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CONTENTS

THE CENTENARY OF THE FRANKLIN INSTITUTE:
THE NATURAL AND ARTIFICIAL DISINTEGRATION OF THE ELEMENTS. Professor Sir Ernest Rutherford 561
THE CARBON ATOM IN CRYSTALLINE STRUCTURE. Sir William Henry Bragg 578
THE BEST USE OF THE WATERS OF THE GREAT LAKES. Dr. John F. Hayford 588
POPULATION AND PROGRESS. Professor George R. Davies 598
BOTANIZING IN ECUADOR. Dr. A. S. Hitchcock 611
MENTAL HYGIENE IN THE UNIVERSITY. Dr. Stewart Paton 625
STABILITY. Professor T. Wingate Todd 632
WHY I TEACH EVOLUTION. Professor William Patten 635
THE PHYSICAL BASIS OF DISEASE. The Research Worker 638
WHO PROFITS FROM SCIENTIFIC WORK? Dr. F. C. Brown 655
THE PROGRESS OF SCIENCE:
Cotton Acquires a New Camouflage; Feeling the Pulse of a Star; Is It Moonshine? 661
INDEX TO VOLUME XIX 671

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THE SCIENTIFIC MONTHLY

DECEMBER, 1924

THE CENTENARY OF THE FRANKLIN INSTITUTE[1]

THE NATURAL AND ARTIFICIAL DISINTEGRATION OF THE ELEMENTS

By Professor SIR ERNEST RUTHERFORD, F.R.S.

TRINITY COLLEGE, UNIVERSITY OF CAMBRIDGE

It is not my intention in this paper to give a detailed account of the natural disintegration of the radio elements or of the methods employed to effect the artificial disintegration of certain light elements. I shall assume that you all have a general knowledge of the results of these investigations, but I shall confine myself to a consideration of the bearing of these results on our knowledge of the structure of the nuclei of atoms.

There is now a general agreement that the atoms of all elements have a similar electrical structure consisting of a central positively charged nucleus surrounded at a distance by the appropriate number of electrons. From a study of the scattering α particles by the atoms of matter and from the classical researches of Moseley on X-ray spectra, we know that the resultant positive charge on the nucleus of any atom, in terms of the fundamental unit of electronic charge, is given numerically by the atomic or ordinal number of the element, due allowance being made for missing elements. We know that with few exceptions all nuclear charges from 1 for the lightest atom hydrogen to 92 for the heaviest element uranium are represented by elements found in the earth. The nuclear charge of an element controls the number and distribution of the external electrons, so that the properties of an atom are defined by a whole number, representing its nuclear charge, and are only to a minor degree influenced by the mass or atomic weight of the atom.

[1] Addresses given at the celebration of the centenary of the founding of the Franklin Institute of Pennsylvania at Philadelphia, published here by the authority of the officers of the institute.

This minute but massive nucleus is, in a sense, a world of its own which is little, if at all, influenced by the ordinary physical and chemical forces at our command. In many respects, the problem of nuclear structure is much more difficult than the corresponding problem of the arrangement and motions of the planetary electrons where we have a wealth of available information, both physical and chemical, to test the adequacy of our theories. The facts known about the nucleus are few in number and the methods of attack to throw light on its structure are limited in scope.

It is convenient to distinguish between the properties assigned to the nucleus and the planetary electrons. The movements of the outer electrons are responsible for the X-ray and optical spectra of the elements and their configuration for the ordinary physical and chemical properties of the element. On the other hand, the phenomena of radioactivity and all properties that depend on the mass of the atom are to be definitely assigned to the nucleus. From a study of the radioactivity transformations, we know that the nucleus of a heavy atom not only contains positively charged bodies but also negative electrons, so that the nuclear charge is the excess of positive charge over negative. In recent years, the general idea has arisen that there are two definite fundamental units that have to do with the building up of complex nuclei, *viz.*, the light negative electron and the relatively massive hydrogen nucleus which is believed to correspond to the positive electron.

This view has received very strong support from the experiments of Aston on isotopes in which he has shown that the masses of the various species of atoms are represented nearly by whole numbers in terms of $O = 16$. From the general electric theory, it is to be anticipated that the mass of the hydrogen nucleus in the nucleus structure will be somewhat less than its value 1.0077 in the free state on account of the very close packing of the charged units in the concentrated nucleus. From Aston's experiments, it appears that the average mass of the hydrogen nucleus or proton, as it is now generally called, is very nearly 1.000 under these conditions. We should anticipate that the whole number rule found by Aston would hold only to a first approximation since the mass of the proton must be to some extent dependent on the detailed structure of the nucleus. In the case of tin and xenon, Aston has already signalized a definite departure from the whole number rule and no doubt a still more accurate determination of the masses of the atoms will disclose other differences of a similar kind.

While our present evidence indicates that the proton and electron are the fundamental constituents of the nucleus, it is very probable that secondary combining units play a prominent part in

nuclear constitution. For example, the expulsion of helium nuclei from the radioactive bodies indicates that the helium nucleus of mass four is probably a secondary unit of great importance in atom building. On the views outlined, we should expect the helium nucleus of charge two to be built up of four protons and two electrons. The loss of mass in forming this nucleus indicates that a large amount of energy must be liberated during its formation. If this be the case, the helium nucleus must be such a stable structure that the combined energy of four or five of the swiftest α particles would be necessary to effect its disruption. Such a deduction is supported by our failure to observe any evidence of disintegration of the swift particle itself, whether it is used to bombard matter or whether the α particle is used to bombard other helium atoms.

On these views, we should anticipate that the nucleus of radium of atomic number 88 and atomic weight 226 contains in all 226 protons of mass 1. and 138 electrons. While this gives us the numerical relation between the two fundamental units, we have, at present, no definite information of their arrangement in the minute nuclear volume nor of the nature and magnitude of the forces that hold them together. We should anticipate that many of the protons and electrons unite to form secondary units, *e.g.*, helium nuclei, and that the detailed structure of the nucleus may be very different from that to be expected if it consists of a conglomeration of free protons and electrons.

It is thus of great importance to obtain definite evidence of the nature and arrangement of the components of the nucleus and of the forces that hold them in equilibrium. We shall now consider some of the lines of evidence which throw light on the actual dimensions of the nucleus and the law of force operative in its neighborhood; the structure and modes of vibration of the nucleus together with the effects observed when some light nuclei are disintegrated by bombardment with particles.

Dimensions of the Nuclei and the Law of Force

The conception of the nucleus atom had its origin in 1911 in order to explain the scattering of an α particle through a large angle as the result of a single collision. The observation that the α particle is in some cases deflected through more than a right angle as the result of an encounter with a single atom first brought to light the intense forces that exist close to the nucleus. Geiger and Marsden showed that the number of particles scattered through different angles was in close accord with the simple theory which supposed that, for the distance involved, the α particle and nucleus behaved like charged points repelling each other according to the law of the

inverse square. The accuracy of this law has been independently verified by Chadwick, so that we are now certain that in a region close to the nucleus the ordinary laws of force are valid.

These scattering experiments also gave us the first idea as to the probable dimensions of the nuclei of heavy atoms, for it is to be anticipated that the law of the inverse square must break down if the α particle approaches closely to, or actually enters the nuclear structure. This variation in the law of force would show itself by a difference between the observed and calculated numbers of particles scattered through large angles. Geiger and Marsden, however, observed no certain variation even when the α particles of range about 4 cms were scattered through 100° by a gold nucleus. In such an encounter, the closest distance of approach of the particle to the center of the nucleus is about 5×10^{-12} cm, so that it would appear that the radius of the gold nucleus, assumed spherical, could not be much greater than this value.

There is another argument, based on radioactive data, which gives a similar value for the dimensions of the radius of a heavy atom. The α particle escaping from the nucleus increases in energy as it passes through the repulsive field of the nucleus. To fix a minimum limit, suppose the α particle from uranium gains all its energy from the electrostatic field. It can be calculated on these data that the radius of the uranium nucleus can not be less than 6×10^{-12} cm. This is based on the assumption that the forces outside the nucleus are repulsive and purely electrostatic. If, as seems not unlikely, there also exists close to the nucleus strong attractive forces, varying more rapidly than an inverse square law, the actual dimensions may be less than the value calculated above.

At this stage of our knowledge, it is of great importance to test whether the law of force breaks down for the distance of closest approach of an α particle to a nucleus. This can be done by comparing the observed with the calculated number of α particles scattered through angles of nearly 180°. It seems almost certain that the inverse square law must break down when swift α particles are used. This can be seen from the following simple argument. If an α particle, of the same speed as that ejected during the transformation of uranium, is fired directly at the uranium nucleus, *it must penetrate into the nuclear structure.* If a still swifter α particle is used, *e.g.*, that from radium C, which has about twice the energy of the uranium α particle, it is clear that it must penetrate still more deeply into the nuclear structure. This is based on the assumption that the field due to a nucleus is approximately symmetrical in all directions. If this is not true, it may happen

that only a fraction of the head-on collisions may be effective in penetrating the nucleus. It is hoped soon to attack this difficult problem experimentally.

We have so far dealt with collisions of an α particle with a heavy atom. We know, however, from the results of Rutherford, Chadwick and Bieler that in a collision of an α particle with the lightest atom, hydrogen, the law of the inverse square breaks down entirely when swift particles are used. Not only are the numbers of H nuclei set in swift motion much greater than is to be expected in the simple-point nucleus theory, but the change of number with the velocity of the α particle varies in the opposite way from the simple theory. Such wide departures between theory and experiment are only explicable if we assume either that the nuclei have sensible dimensions or that the inverse square law of repulsion entirely breaks down in such close collisions. If we suppose the complexity in structure and in laws of force is to be ascribed to the α particle rather than to the hydrogen nucleus, Chadwick and Bieler, as the result of a careful series of experiments, concluded that the α particle behaved as if it were a perfectly elastic body, spheroidal in shape with its minor axis at 4×10^{-13} cms in the direction of motion and major axis 8×10^{-13} cms. Outside this spheroidal region, the forces fell off according to the ordinary inverse square law, but inside this region the forces increased so rapidly that a particle was reflected from it as from a perfectly elastic body. No doubt such a conception is somewhat artificial, but it does serve to bring out the essential points involved in the collision, *viz.*, that when the nuclei approach within a certain critical distance of each other, forces come into play which vary more rapidly than the inverse square. It is difficult to ascribe this breakdown of the law of force merely to the finite size or complexity of the nuclear structure or to its distortion, but the results rather point to the presence of new and unexpected forces which come into play at such small distances. This view has been confirmed by some recent experiments of Bieler in the Cavendish Laboratory in which he has made, by scattering methods, a detailed examination of the law of force in the neighborhood of a light nucleus like that of aluminum. For this purpose he compared the relative number of α particles scattered within the same angular limit from aluminum and from gold. For the range of angles employed, *viz.*, up to 100°, it is assumed that the scattering of gold follows the inverse square law. He found that the ratio of the scattering in aluminum compared with that in gold depended on the velocity of the α particle. For example, for an α particle of 3.4 cm range, the theoretical ratio

was obtained for angles of deflection below 40° but was about 7 per cent. lower for an average angle of deflection of 80°. On the other hand, for swifter particles of range 6.6 cms, a departure from the theoretical ratio was much more marked and amounted to 29 per cent. for an angle of 80°. In order to account for these results he supposes that close to the aluminum nucleus, an attractive force is superimposed on the ordinary repulsive forces. The results agreed best with the assumption that the attractive force varies according to the inverse fourth power of the distance and that the forces of attraction and repulsion balanced at about 3.4 c 10^{-13} cms from the nuclear center. Inside this critical radius, the forces are entirely attractive; outside it they are repulsive.

While we need not lay too much stress on the accuracy of the actual value obtained or of the law of attractive force, we shall probably not be far in error in supposing the radius of the aluminum nucleus is not greater than 4 x 10^{-13} cm. It is of interest to note that the forces between an α particle and a hydrogen nucleus were found to vary rapidly at about the same distance.

It thus seems clear that the dimensions of the nuclei of light atoms are small, and almost unexpectedly small, in the case of aluminum, when we remember that 27 protons and 14 electrons are concentrated in such a minute region. The view that the forces between nuclei change from repulsion to attraction when they are very close together seems very probable, for otherwise it is exceedingly difficult to understand why a heavy nucleus with a large excess of positive charge can hold together in such a confined region. We shall see that the evidence from various other directions supports such a conception, but it is very unlikely that the attractive forces close to a complex nucleus can be expressed by any simple power law.

Radioactive Evidence

A study of the long series of transformations which occur in uranium and thorium provides us with a wealth of information on the modes disintegration of atoms, but unfortunately our theories of nuclear structure are not sufficiently advanced to interpret these data with any detail. The expulsion of high speed α and β particles from the radioactive nucleus gives us some idea of the powerful forces resident in the nucleus, for it can be estimated that the energy of emission of the α particle is in some cases greater than the energy that would be acquired if the particle fell freely between two points differing in potential by about four million volts. The energies of the β and γ rays are on a similar scale of magnitude.

Notwithstanding our detailed knowledge of the successive transformation of the radio elements, we have not so far been able to

obtain any definite idea of their nuclear structure, while the cause of the disintegration is still a complete figure. In comparing the uranium, thorium and actinium series of transformations, one can not fail to be struck by the many points of similarity in their modes of disintegration. Not only are the radiations similar in type and in energy but, in all cases, the end product is believed to be an isotope of lead. This remarkable similarity in the modes of transformation is especially exemplified in the case of the "C" bodies, each of which is known to break up in at least two distinct ways, giving rise to branch products. For example, thorium C emits two types of α rays, 65 per cent. of range 8.6 cms, and 35 per cent. of range 4.8 cms, and in addition some β rays.

In order to explain these results, it has been suggested that a fraction of the atoms of thorium C break up first with the expulsion of an α particle and the resulting product then emits a β particle. The other fraction breaks up in a reverse way, first expelling a β particle, while the subsequent product emits an α particle. Similar dual changes occur in radium C and actinium C, although the relative number of atoms in each branch varies widely for the different elements.

This remarkable similarity between the "C" bodies is still further emphasized by the recent discovery of Bates and Rogers that both radium C and thorium C give rise in small numbers to other groups of α particles, some of them moving at very high speeds.

It has often been a matter of remark that the radioactive properties of the "C" bodies seem to depend more on the atomic number, *i.e.*, the nuclear charge, than on the atomic weight. Confining our attention to radium C and thorium C, which are best known, both have a nuclear charge 83, but the atomic mass of radium C is 214 and of thorium C 212. The nucleus of radium C thus contains two protons and two electrons more than that of thorium C. If it were supposed that the nuclei of these elements consisted of a large number of charged units in ceaseless and irregular motion, it is to be anticipated that the addition of the protons and electrons to the complex structure would entirely alter the nuclear arrangement and consequently its stability and mode of transformation. On the other hand, we find that the modes of transformation of these two nuclei have striking and unexpected points of resemblance which are in entire disaccord with such a supposition. We can, however, suggest a possible explanation of this anomaly by supposing that the α and β particles which are liberated from these elements are not built deep into the nuclear structure but exist as *satellites* of a central core which is common to both elements. These satellites, if

in motion, may be held in equilibrium by the attractive forces arising from the core and these forces would be the same for both elements. On this view the manifestations of radioactivity are to be ascribed, not to the main core, but to the satellite distribution, which must be somewhat different for the two elements, although possibly showing many points of similarity. It must be admitted that a theory of this kind is highly speculative, but it does provide a useful working hypothesis, not only to account for the similarity of the modes of transformation of the two elements but also immediately suggests a possible explanation of the liberation of a number of α particles of different ranges from the same element. There are two ways of regarding this question. We may in the first place suppose that a certain amount of surplus energy has to be liberated in the disintegration and that this energy may be given to any one of a number of satellites. There will be a certain probability that any particular particle will be given this energy and on this will depend the relative number of particles in the different α ray groups. The ultimate energy of ejection of an α particle will depend on its position in the field of force surrounding the inner core at the moment of its liberation. On the other hand, we may suppose that the same α particle is always ejected, but that the particle may occupy in the atom one of a number of "stationary" positions analogous to the "stationary states" of the electrons in Bohr's theory of the outer atom. This rests on the assumption that all the atoms will not be identical in satellite structure, but there will be a number of possible "excited" states of the atom as a consequence of the previous disintegrations. This satellite theory is useful in another connection. It has been suggested that possibly the high frequency γ rays from a radioactive atom may arise not from the movement of the electrons as ordinarily supposed, but from the transfer of particles from one level to another. In such a case, the difference in energies between the various groups of α particles from radium C and thorium C should be connected by the quantum relation with the frequencies of prominent γ rays. The evidence at present available is not definite enough to give a final decision on this problem but points to the need of very accurate measurements of the energies of the various groups of α particles. On account of the relatively small number of particles in some of the groups, this is difficult of accomplishment.

In considering the satellite theory in connection with the radioactive bodies, it is at first sight natural to suppose, since the end product of both the radium and thorium series is an isotope of lead, that one of the isotopes of lead forms the central core. It may, however, well be that the radioactive processes cease when there are

still a number of satellites remaining. If this be so, the core may be of smaller nuclear charge and mass than that of lead. From some considerations, described later, this core may correspond to an element near platinum of number 77 and mass 192.

Frequency of Vibration of the Nucleus

One of the most interesting and important methods of throwing light on nuclear structure is the study of the very penetrating γ rays expelled by some radioactive bodies. The γ rays are identical in nature with X-rays, but the most penetrating type of rays consists of waves of much higher frequency than can be produced in an ordinary X-ray tube. The work of the last few years has indicated very clearly that the major part of the radiation from bodies, like radium B and C, originates in the nucleus. A determination of the frequencies of the γ rays thus gives us direct information on the modes of vibration of parts of the nuclear structure. The frequency of some of the softer γ rays excited by radium B and radium C were measured by the crystal method by Rutherford and Andrade, but it is difficult, if not impossible, by this method to determine the frequencies of the very penetrating rays. Fortunately, due largely to the work of Ellis and Fraulein Meitner, a new and powerful method has been devised for this purpose. It is well known that the β rays from radium B and radium C give a veritable spectrum in a magnetic field showing the presence of a number of groups of β rays each expelled with a definite speed. It is clear that each of the groups of β rays arises from conversion of the energy of a γ ray of definite frequency into a β ray in one or other of the electronic levels in the outer atom. The energy ω required to move an electron from one of these levels to the outside of the atom is known from a study of X-ray absorption spectra. The frequency γ of the γ ray is thus given by the quantum relation $h\nu = E + \omega$, where E is the measured energy of the β particle.

Since each γ ray may be converted in any one of the known electronic levels in the outer atom, a single γ ray is responsible for the appearance of a number of groups of β rays, corresponding to conversion in the K, L, M, etc., levels. In this way, an analysis of the β ray spectrum allows us to fix the frequency of the more intense γ rays which are emitted from the nucleus. The energy of the shortest wave measured in this way by Ellis corresponds to more than two million volts, while other evidence shows that probably still shorter waves are emitted in small quantity from radium C.

Ellis and Skinner have shown that the energies of these rays show certain combination differences, such as are so characteristic of the energies of the X-rays arising from the outer electrons. A

series of energy levels may thus be postulated in the nucleus similar in character to the electron levels of the outer atom and the γ rays have their origin in the fall, either of an electron or of an α particle between these levels. This is a significant and important result indicating that the quantum dynamics can be applied to the nucleus as well as to the outer electronic structure.

The probability of levels in the nuclear structure is most clearly seen on the satellite hypothesis, but in our ignorance of the laws of force near the core, we are at the moment unable to apply the quantum dynamics directly to the problem. The outlook for further advances in this direction is hopeful, but is intimately connected with further development of our knowledge of the laws of force that come into play close to the nucleus in the region occupied by the satellites.

Artificial Disintegration of Elements

We have seen that it is believed that the nuclei of all atoms are composed of protons and electrons and that the number of each of these units in any nucleus can be deduced from its mass and nuclear charge. It is, however, at first sight rather surprising that no evidence of the individual existence of protons in a nucleus is obtained from a study of the transformations of the radioactive elements, where the processes occurring must be supposed to be of a very fundamental character. As far as our observations have gone electrons and helium nuclei but no protons are ejected during the long series of transformations of uranium, thorium and actinium. One of the most obvious methods for determining the structure of a nucleus is to find a method of disintegrating it into its component parts. This is done spontaneously for us by nature to a limited extent in the case of the heavy radioactive elements, but evidence of this character is not available in the case of the ordinary elements. As the swift α particle from the radioactive bodies is, by far, the most energetic projectile known to us, it seemed from the first possible that occasionally the nucleus of a light atom might be disintegrated as the result of a close collision with an α particle. On account of the minute size of the nucleus, it is to be anticipated that the chance of a direct hit would be very small and that consequently the disintegration effects, if any, would be observed only on a very minute scale. During the last few years, Dr. Chadwick and I have obtained definite evidence that hydrogen nuclei or protons can be removed by bombardment of α particles from the elements boron, nitrogen, fluorine, sodium, aluminum and phosphorus. In these experiments, the presence of H nuclei is detected by the scintillation method, and their maximum velocity of ejection can be estimated from the thickness of matter which can be penetrated by these particles. The

number of H nuclei ejected even in the most favorable case is relatively very small compared with the number of bombarding α particles, *viz.*, about one in a million.

In these experiments the material subject to bombardment was placed immediately in front of the source of α particles and observations on the ejected particles were made on a zinc sulphide screen placed in a direct line a few centimeters away. Using radium C as a source of α rays, the ranges of penetration expressed in terms of centimeters of air were in all these cases greater than the range of free nuclei (30 cms in air) set in motion in hydrogen by the α particles. By inserting absorbing screens of 30 cms air equivalent in front of the zinc sulphide screen the results were quite independent of the presence of either free or combined hydrogen as an impurity in the bombarded materials. Some of the lighter elements were examined for absorptions less than this but, in general, the number of H particles due to hydrogen contamination of the source and the materials was so large that no confidence could be placed in the results.

In such experiments many scintillations can be observed, but it is very difficult to decide whether these can be ascribed in part to an actual disintegration of the material under examination. The presence of long range particles of the α ray type from the source of radium C still further complicates the question, since in general the number of such particles is large compared with the disintegration effect we usually observe.

To overcome these difficulties, inherent in the direct method of observation, Dr. Chadwick and I have devised a simple method by which we can observe with certainty the disintegration of an element when the ejected particles have a range of only 7 cms in air. This method is based on the assumption, verified in our previous experiments, that the disintegration particles are emitted in all directions relative to the incident rays. A powerful beam of α rays falls on the material to be examined and the liberated particles are observed at an average angle of 90° to the direction of the incident α particles. By means of screens it is arranged that no α particles can fall directly on the zinc sulphide screen.

This method has many advantages. We can now detect particles of range more than 7 cms, with the same certainty as particles of range above 30 cms, in our previous experiments, for the presence of hydrogen in the bombarded material has no effect. This can be shown at once by bombarding a screen of paraffin wax, when no particles are observed on the zinc sulphide screen. On account of the very great reduction in number of H nuclei or α particles by scattering through 90°, the results are quite independent of

H nuclei from the source or of the long range α particles. The latter are just detectable under our experimental conditions when a heavy element like gold is used as scattering material, but are inappreciable for the lighter elements.

A slight modification of the arrangement enables us to examine gases as well as solids.

Working in this way we have found that in addition to the elements boron, nitrogen, fluorine, sodium, aluminum and phosphorus, which give H particles of maximum range in the forward direction between 40 and 90 cms, the following give particles of range above 7 cms, neon, magnesium, silicon, sulphur, chlorine, argon and potassium. The numbers of the particles emitted from these elements are small compared with the number from aluminum under the same conditions, varying between one third and one twentieth. The ranges of the particles have not been determined with accuracy. Neon appears to give the shortest range, about 16 cm, under our conditions, the ranges of the others lying between 18 cm and 30 cm. By the kindness of Dr. Rosenhain we were able to make experiments with a sheet of metallic beryllium. This gave a small effect about one thirtieth of that of aluminum, but we are not yet certain that it may not be due to the presence of a small quantity of fluorine as an impurity. The other light elements, hydrogen, helium, lithium, carbon and oxygen, give no detectable effect beyond 7 cm. It is of interest to note that while carbon and oxygen give no effect, sulphur, also probably a "pure" element of mass 4n, gives an effect of nearly one third that of aluminum. This shows clearly that the sulphur nucleus is not built up solely of helium nuclei, a conclusion also suggested by its atomic weight of 32.07.

We have made a preliminary examination of the elements from calcium to iron, but with no definite results, owing to the difficulty of obtaining these elements free from any of the "active" elements, in particular, nitrogen. For example, while a piece of electrolytic iron gave no particles beyond 7 cms, a piece of Swedish iron gave a large effect which was undoubtedly due to the presence of nitrogen, for after prolonged heating *in vacuo* the greater part disappeared. Similar results were experienced with the other elements in this region.

We have observed no effects from the following elements: nickel, copper, zinc, selenium, krypton, molybdenum, palladium, silver, tin, xenon, gold and uranium. The krypton and xenon were kindly lent by Dr. Aston.

Examination of Light Elements for Particles of Range less than 3 cms of Air

When α particles are scattered from light elements, the simple theory shows that the velocity of the scattered particles depends on the angle of scattering. For example, using bombarding α particles of range 7 cms, the range of the α particles scattered through more than 90° can not be greater than 1.0 cms for lithium (7), 2.0 cms for beryllium, (10), 2.5 cms for carbon, 3.2 cms for oxygen, 4.3 cms for aluminum and 6.8 cms for gold.

Provided we introduce sufficient thickness of absorber to stop the α particles scattered through 90°, we can examine for disintegrated particles from carbon, for example, whose range exceeds 2.5 cms. Certain difficulties arise in this type of experiment which are absent when the thickness of absorber is greater than 7 cms; any heavy elements present as an impurity will give scattered α particles of range greater than those from carbon and thus complicate the observations. In addition, serious troubles may arise due to the volatilization or escape of active matter from the source. This is especially marked if the vessel containing the radioactive source is exhausted. To overcome this difficulty, we have found it desirable to cover the source with a thin layer of celluloid of 2 or 3 mm stopping power for α rays. By this procedure, we have been able to avoid serious contamination and to examine the lighter elements by this method. We have been unable to detect any appreciable number of particles from lithium or carbon for ranges greater than 3 cms. If carbon shows any effect at all, it is certainly less than one tenth of the number from aluminum under the same conditions. This is in entire disagreement with the work of Kirsch and Patterson (*Nature*, April 26, 1924), who found evidence of a large number of particles from carbon of range 6 cms. A slight effect was observed in beryllium in accordance with our other experiments. No effect was noted in oxygen gas. Apart from beryllium, no certain effect has been noted for elements lighter than boron.

Under the conditions of our experiment, it seems clear that neither H nuclei nor other particles of range greater than 3 cms can be liberated in appreciable numbers from these elements in a direction at right angles to the bombarding α rays. This is, in a sense, a disappointing result, for, unless these elements are very firmly bound structures, it was to be anticipated that an α particle bombardment would receive them into their constituent particles.

We hope to examine this whole question still more thoroughly, as it is a matter of great importance to the theory of nuclear constitution to be certain whether or not the light elements can be discharged by swift α particles.

In considering the results of our new and old observations, some points of striking interest emerge. In the first place, all the elements from fluorine to potassium, inclusive, suffer disintegration under α ray bombardment. As far as our observations have gone, there seems little doubt that the particles ejected from all these elements are H nuclei. The odd elements B, N, Fl, Wa, Al, P, all give long range particles varying in range from 40 cms to 90 cms in the forward direction; the even elements C, O, Ne, Mg, Si, S, either give few or none at all, as in the case of C and O, or give particles of much less range than the adjacent odd-numbered elements. The difference between the range of even–odd elements becomes much less marked for elements heavier than phosphorus.

This obvious difference in velocity of expulsion of the H nuclei from even and odd elements is a matter of great interest. Such a distinction can be paralleled by other observations of an entirely different character. Harkins has shown that elements of even atomic number are much more abundant in the earth's crust than elements of odd atomic number. In his study of isotopes, Aston has shown that in general odd-numbered elements have only two isotopes differing in mass by two units, while even-numbered elements in some cases contain a large number of isotopes. This remarkable distinction between even and odd elements can not but excite a lively curiosity, but we can at present only speculate on its underlying cause.

Velocity of Escape of Hydrogen Nuclei

We have seen that the experiments of Bieler on the scattering of X-rays by aluminum and magnesium indicate that a powerful attractive force comes into play very close to the nuclei of these atoms. If this be the case, the forces of attraction and repulsion must balance at a certain distance from the nucleus. Outside this critical point the forces on a positively charged body are entirely repulsive. Certain important consequences follow from this general view of nuclear forces. Suppose, for example, that, due to a collision with a swift α particle, a hydrogen nucleus is liberated from the nuclear structure. After passing across the critical surface, it will acquire energy in passing through the repulsive field. It is clear, on this view, that the energy of a charged particle after escape from the atom can not be less than the energy acquired in the repulsive field; consequently we should expect to find evidence that there is a minimum velocity of escape of a disintegration particle. We have obtained definite evidence of such an effect both in aluminum and sulphur by examining the absorption of H nuclei from these elements. The number of scintillations for a thin film

was found to be nearly constant for absorption between 7 and 12 cms, but falls off rapidly for greater thickness. This is exactly what is to be expected on the views outlined. No doubt the limiting velocity varies somewhat for the different elements, but a large amount of experiment will be required to fix this limit with accuracy. From these results, it is possible to form a rough estimate of the potential of the field at the critical surface and this comes out to be about three million volts for aluminum. The value for sulphur is somewhat greater. This brings out in a striking way the extraordinary smallness of the nuclei of these elements, for it can be calculated that the critical surface can not be distant more than 6×10^{-13} cm from the center of the nucleus. These deductions of the critical distance are in excellent accord with those made by Bieler from observations of the scattering of α particles.

Another important consequence follows. It is clear that an α particle fired at the nucleus will not be able to cross this critical surface and thus be in a position to produce disintegration, unless its velocity exceeds that corresponding to the critical potential. In an experiment made a few years ago, we found that the number of H nuclei liberated from aluminum fell off rapidly with diminution of the velocity of the α particle and was too small in number to detect when the range of the α particle was less than 4.9 cms. This corresponds to the energy of an α particle falling between about three million volts—a value in good accord with that calculated from the escape of H nuclei.

Further experiments are required with other elements to test if this relation between the minimum velocity of H nuclei and the minimum velocity of the α particle to produce disintegration, holds generally; but the results as far as they go are certainly very suggestive.

It is of interest to note that these results afford a definite proof of the nuclear conception of the atom and give us some hope that we may determine the magnitude of the critical potential for a number of the light elements.

Evolution of Nuclei

In concluding, I would like to make a few remarks of a more speculative character dealing with the fundamental problem of the origin and evolution of the elements from the two fundamental building units, the positive and negative electrons. It must be confessed that there is little information to guide us with the exception of our knowledge of the nuclear charges and masses of the various species of elements which survive to-day. It has always been a matter of great difficulty to imagine how the more complex nuclei

can be built up by the successive additions of protons and electrons, since the proton must be endowed with a very high speed to approach closely to the charged nucleus. I have already discussed in this paper the evidence that powerful attractive forces varying very rapidly with the distance are present close to the nuclear structure and it seems probable that these forces must ultimately be ascribed to the constituent proton. In such a case, it may be possible for an electron and proton to form a very close combination, or neutron, as I have termed it. The probable distance between the center of this doublet is of the order of 3×10^{-13} cms. The forces between the two neutrons would be very small except for distance of approach of this order of magnitude, and it is probable that the neutrons would collect together in much the same fashion as a number of small movable magnets would tend to form a coherent group held together by their mutual forces.

In considering the origin of the elements, we may for simplicity suppose a large diffused mass of hydrogen which is gradually heated by its gravitational condensation. At high temperatures, the gas would consist mainly of free hydrogen nuclei and electrons, and some of these would in course of time combine to form neutrons emitting energy in the process. These neutrons would collect together in nuclear masses of all kinds of complexity. Now the tendency of the groups of neutrons would be to form more stable nuclear combinations, such as helium nuclei of mass four, and possibly intermediate stages of masses two and three. Energy would be emitted in these processes probably in the form of swift surplus electrons which were not necessary for the stability of the system. In a sense, all these nuclear masses would be radioactive, but some of them in their transformation may reach a stable configuration which would represent the nucleus of one of our surviving elements. If we suppose that nuclear masses over a wide range of mass can be formed before serious transformation occurs, it is easy to see how every possible type of stable element will gradually emerge. If we take the helium nucleus as a combining unit which emits in its formation the greatest amount of energy we should ultimately expect many of the neutrons in a heavy nucleus to form helium nuclei. These helium nuclei would tend to collect together and form definite systems and it seems not unlikely that they will group themselves into orderly structures, analogous in some respects to the regular arrangement of atoms to form crystals, but with much smaller distances between the structural units. In such a case, some of the elements may consist of a central crystal type of structure of helium nuclei surrounded by positive and negatively charged satellites in motion round this central core. Assuming that such orderly

arrangements of helium nuclei are possible, it is of interest to note that the observed relations between atomic charges and atomic mass for the elements can be approximately obtained on a very simple assumption. Suppose that helium nuclei form a point centered cubic lattice with an electron at the center of a crystal unit of eight helium nuclei. A few of the possible types of grouping are given in the following table with corresponding masses and nuclear charges. The structure 4. 3. 2. means a rectangular arrangement with sides containing 4. 3. 2. nuclei, respectively. It will thus contain 24 helium nuclei, have a mass 96, and will contain 6 intranuclear electrons. Its nuclear charge will therefore be $48 - 6 = 42$.

Structural arrangement of helium nuclei	Calculated nuclear charge	Calculated mass	Known element of equal charge
3. 2. 2.	22	48	Ti 48
3. 3. 2.	32	72	Ge 74, 72, 70
3. 3. 3.	46	108	Pa 106.7
4. 2. 2.	29	64	Cu 63.35
4. 3. 2.	42	96	Mo 96
4. 3. 3.	60	144	Nd 144
4. 4. 3.	78	192	Pt 195

While the arrangement is far from perfect for all these structures, there is a general accord with observation. If we take the view that some of these structures can grow by the addition of satellites, there is room for adjustment of masses and to include the intervening elements. This point of view is admittedly very speculative, and there may well be other types of structure involved. At the same time, the general evidence suggests that there are some basal structures on which the heavier atoms are progressively built up. The failure of the whole number rule for the mass of isotopes, observed in some cases by Aston, *e.g.*, between tin and xenon, certainly supports such a conception. From a study of the artificial disintegration of the elements we have seen that carbon and oxygen represent very stable structures probably composed of helium nuclei. It is possible that oxygen nuclei, for example, may be the structural basis of some of the elements following oxygen, but our information is at present too meager to be at all certain on this point.

I think, however, it will be clear from this lecture what a difficult but fascinating problem is involved in the structure of nuclei. Before we can hope to make much advance, it is essential to know more of the nature of the forces operative close to protons and electrons, and we may hope to acquire much information by a detailed study of the scattering of swift α rays and β rays by nuclei. Fortunately, there is now a number of distinct lines of attack in

this problem, and from a combination of the results obtained, we may hope to make steady, if not rapid, progress in the solution of this, the greatest problem in physics.

THE CARBON ATOM IN CRYSTALLINE STRUCTURE

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It is one of the great purposes of research to be able to explain the properties of materials in terms of the properties of their parts. The division into parts may be carried to various degrees of fineness; and the nature of the research, its methods and difficulties, and the expectations of success will depend on the division that is attempted. The properties of a piece of steel may to some extent be explained in terms of the small visible particles, crystalline or of which it is composed; the degree of division is determined by the power of the microscope, and results of great value are obtained within this range. But we may have, as a higher ideal, the hope of explaining the qualities of steel in terms of the properties of the atoms of iron and carbon and other constituent elements. The division is far finer than the other; but obviously far more complete and satisfying. The difficulties are great, but so also will be, we may be sure, the ultimate success. And generally it must be our aim to explain the properties of all materials in terms of the atoms, remarkably limited in kind, of which the world is made.

Some progress towards the ideal has been made in the case of the gas and the liquid states; the great effort is yet to be made in the case of the solid. The moving particles of a gas are free from each other's influence for the most part of their time; they can be heated as projectiles whose rare encounters are but slightly affected by the special and peculiar attractions which they exert on each other when very close together. The properties of gases are to a certain extent explainable in terms of a pure kinetic theory. Complications arise when from any cause the times during which the atoms or molecules are under each other's influence become relatively important, and the consequences depend on the individual peculiarities.

So also in the case of liquids much can be explained on a purely hydrodynamical theory, especially when the ties between atoms and molecules can be dissolved and reformed continually without waste of energy in the form of heat, that is to say, when there are no viscosity effects. But when viscosity is to be taken account of, then the peculiar and individual actions of the atoms and molecules must be treated as effective. Still more, the phenomena of surface

tension are direct manifestations of the forces that the atoms exert on their neighbors; and so in general are all the effects studied by the physical chemist. We are yet very far from being able to unravel them.

It is true that the associations and dissolutions of chemical action are due directly to the characteristic forces exerted by the atoms; and that chemical studies afford a most important means of examining them. Nevertheless, we want more than chemistry gives us if we are to reach our object. For instance, we are far from linking up the properties of quartz with the known chemistry of silicon and oxygen.

In general, we know very little of the relation between the properties of the solid material and of the atoms of which it is built. Of the relation between the molecule and its constituent atoms we do know something, thanks to chemical study. But the wide field of solid structure is in this respect almost unexplored. The reason for this is very simple. The properties of the solid depend upon the structural arrangement of its component atoms which arrangement is at the first attempt, as we may say, crystalline. When groups of atoms or molecules associate and form a solid, they arrange themselves in a regular pattern; the unit of pattern containing only a few groups, usually two, three, four, six or other small numbers. The arrangement is so uniform and so exact as to imply that the group has a definite and characteristic shape, or, in other words, that the forces which one group, atom or molecule exerts on its neighbors are such as to place them at proper distances from itself and in proper orientations. The crystal is the direct expression of this tendency and is a far more prevalent form of matter than we had thought. The large crystals that we see with our naked eye, and even the small crystals which the microscope reveals to us are only the favorable cases. Below all that we can see in any way is a universal tendency to crystallization which the methods of X-ray analysis are now showing to us. The solid which appears to us to possess none of the properties of the crystal is usually a very viscous body or a disordered mass of minute crystals. The crystal is the simple body, the so-called isotopic body is the complex. Consequently, it is the crystal that must first be mastered.

It is only within the last ten years that the direct study of crystal structure has been possible and the way to this huge field of inquiry been thrown open. The X-rays, to put it simply, if somewhat crudely, are a form of light ten thousand times finer than visible light, and we are now able to see, indirectly it may be, the actual arrangement of the atoms. Here is our chance of making

this supreme analysis. We have before us a wide-spread research, in the course of which we must examine crystal after crystal, learning its structure, that is to say, the pattern according to which its constituent atoms are arranged, and examining the way in which the properties of the individuals determine that pattern and in turn the pattern determines the elasticities, rigidities, conductivities, dielectric capacities and every other characteristic which the crystal possesses. After that, follows in its turn the crystal conglomerate, the isotropic solid.

An especial interest is attached to all that we can discover by the new methods of crystal analysis concerning the nature and properties of the carbon atom. It is not one of the more common elements. While oxygen is calculated to form half the materials of the earth's crust, silicon a quarter and aluminum about a sixteenth, only about a thousandth is composed of carbon. But it is the carbon atom which more than any other impresses its character on the materials of which living bodies are composed. The very term, organic chemistry, which is given to the subject that is largely occupied with the study of the carbon compounds, is an expression of the importance of the carbon atom in the living organism. And not only is the carbon molecule of supreme importance in the constitution of our bodies and of their unconscious actions, but also in a great proportion of the external activities in which we are engaged. We must be especially eager to know what we may learn of the behavior of the carbon atom when it takes part in the constitution of the solid body, and in the first place of the crystal which is the simplest form of the solid. The only fact which makes us hesitate is the vastness of the number of known crystalline compounds, giving us a bewildering choice of material on which to work.

We come to this study with certain expectations founded on the large labors of the organic chemist and their rich harvest of results. We expect the carbon atom to display, for example, a definite tetravalency, a power of attracting to itself under certain circumstances at least four other atoms and no more, all bound in a similar way to the central carbon; as, for example, when the carbon atom draws to itself four atoms of hydrogen and the methane molecule is formed. Yet, under other circumstances, the carbon atom seems fairly content with a smaller number, as when in the benzene ring each carbon is attached to two other carbons and only one hydrogen, and the benzene molecule has very little general attraction for another benzene molecule. Again in the carbon dioxide molecule, the carbon atom is satisfied by the companionship of two other atoms only, and we should like to know which re-

arrangement has been made of its activities to permit the formation of this self-contained molecule, so independent that it forms a gas. And what further change has been made when the molecule of carbon monoxide is constituted? In other words, what is the explanation of the single, double and triple bonds known to the chemist? We hope to be able to throw light on all these phenomena and the questions to which they give rise by the study of the carbon atom as it is built into the crystal where we can examine the exact nature of its evironment and can relate thereto the properties of the crystal.

There are two crystalline forms composed of carbon alone, diamond and graphite, and we naturally turn to their examination first. The diamond structure was, in fact, one of the first to be examined by the new methods. Its structure is very simple and symmetrical and answers at once our expectation that we should find under some circumstances a perfectly tetravalent behavior. Each carbon atom is surrounded by four others, which are grouped about it in perfect symmetry; the atom shows no attraction for more than four. A sphere can, of course, be surrounded by twelve other similar spheres, and if the attraction between any two atoms could be represented merely by a central force, we should expect the close packing which gives the full quota of neighbors. Since there are only four, the force exerted by one carbon atom on another can not be represented by central forces only. Further, the hardness and rigidity of the diamond show us that the forces are mutually oriented; that they are primarily exerted along four lines drawn from the center of a tetrahedron to its corners and that there is a strong resistance to any relative change in those directions. All these new points are in excellent agreement with known chemical facts. The carbon atom is to be represented by a tetrahedron rather than a sphere.

The disposition of the atoms in the diamond shows that they may be divided into two classes, any member of one class being the reflection of the other—with appropriate shift—in any one of three planes which are the cube faces of the crystal. To put this in another form, each diagonal of the cube crystal passes through the vertex and the middle of the base of each class of atom, but members of the two classes face opposite ways. The X-rays detect the difference between the two kinds, from which we conclude that the scatterers of the X-rays participate in the tetrahedral grouping. Yet the difference is only slight, so that if it is the electrons that scatter, they are either close to the center, which seems unlikely, or are not closely pinned down to the corners, so that their diffract-

ing effect would not be large; their action would be like that of broad faint rulings on a diffraction grating.

The other crystal of pure carbon is graphite. There is no clear evidence at present of the existence of any other form, although certain curious carbon materials have not been fully examined. The structure of graphite has recently been reexamined by Bernal, who was able to obtain single crystals of sufficiently perfect form. The results of his work show that graphite is a hexagonal crystal, as Hull had supposed from an examination by the lowder method. It consists of layers of carbon atoms, each layer separated from the next by 3.40 AU, as has long been known. In each layer, the carbon atoms are arranged in a hexagonal network; the long uncertain point as to whether the atoms of one sheet are all exactly in one plane or are in two planes making a puckered network, seems now to be decided in favor of the former alternative, as Debye has suggested. In this case, each carbon atom is very strongly tied to three neighbors all in one plane; the distance between the centers is 1.44 AU as against 1.54 AU in the diamond. The distance between a carbon atom in one layer and its nearest neighbor in the next is more than twice as great. The curious properties of graphite show that the forces between atoms in the same sheet are exceedingly strong, while the forces between sheet and sheet are very small. It is clear that the carbon atom is now exerting its attraction on other atoms in quite a different manner from that which was followed in diamond. If the electrons are in some way responsible for these forces their arrangement must have been altered. The atom is no layer tetrahedral.

The extraordinary success of Bohr's theory in regard to radiation is a constant inducement to attempt a correlation between his arrangement of electron orbits with the display of the atomic forces, although it does not seem possible at present to make more than vague and preliminary attempts in this direction. According to Bohr, there are four electron orbits which we may naturally associate with the tetravalency of the atom; but the four are not all alike, being different, two and two. Thus the tetravalency is not symmetrical. The radiating carbon atom which is the subject of the theory is not, however, attached to other atoms, but is free; and we may well suppose that the internal arrangements are modified by structural requirements. There may be a real difference, implying perhaps a different energy contest between the free atom with its two pairs of outer orbits, the atom in graphite with three like orbits and one odd, and the atom in diamond with all four alike. The electron of the odd orbit in graphite would naturally travel far and be loosely attached to the nucleus; and in this, as

has been suggested by Dr. Shearer and Mr. Bernal, we may find the explanation of the color, the opacity and the conductivity of graphite.

We now come to cases in which other atoms beside the carbon enter into the structure; and first to calcite. The X-ray analysis shows that the carbon atom is now surrounded symmetrically by three atoms of oxygen, all alike.

The compact group of one carbon and three oxygens possesses a double negative charge; the calcium atom possessing the corresponding amount of positive electricity. It has been suggested by Kossel that the arrangement is governed by the tendency for the oxygen atoms to surround themselves in each case by the full complement of eight electrons, and that this is effected by stripping the calcium atom of two electrons and the carbon atom of four. On this theory there is no parallelism with the graphite structure, though in both cases the carbon atom is surrounded by three other coplanar atoms, similarly situated. The carbon atom has now lost all four of the electrons that were moving in outer orbits and is reduced, in external appearance, to helium. It is to be treated as exerting a central electrostatic force due to a positive charge of four units.

It is well known that a vast number of organic substances are based on a substructure consisting of a ring of six carbon atoms, or a chain of carbon atoms of any length. The simplest ring compound is the famous benzene molecule; benzene itself does not, however, lend itself very readily to analysis because benzene is liquid at ordinary temperature and when frozen does not form good crystals. But there are the two substances, naphthalene and anthracene, of which the former has been imagined by the organic chemist to consist of a double ring, represented by two hexagons in the same plane having one side and two corners in common. The latter consists of three hexagons in a line, the naphthalene model extended by one more hexagon. Both these substances crystallize well, a very marked characteristic of each being the tendency to split into thin flakes. All these molecules are bounded by hydrogens as shown in the diagram. They must be considered as simple subjects for attack, because the ring is so common a feature of organic substances and the single, double and triple ring form a series of comparable members. A curious point of obvious interest is the connection of each carbon atom with three, and only three, other atoms. Why has the fourth bond apparently disappeared?

The X-ray analysis shows that the unit of pattern of both naphthalene and anthracene contains two molecules arranged so that their long axes are parallel to one another and that they are the

reflection of each other in the single plane of symmetry which the crystal possesses. In fact the crystal can be considered as a set of parallel flakes, like the monomolecular layers of Langmuir, in each flake the molecules stand not quite at right angles to the flake but leaning over, like wheat in a field blown by the wind. The difference between the anthracene and the naphthalene structures lies only in the length of the molecule, which makes the flaky thickness of the former greater than that of the latter. Moreover, the actual increase in length which is found by the X-ray measurement is exactly what it should be if, in the first place, the one molecule consists of three benzene rings in a row and the other of only two, according to chemical theory, and in the second place, the width of the ring is the same as that of the carbon ring which is found everywhere in the diamond structure. We might suppose in fact that the molecule of naphthalene as built into the crystal structure was simply carved out of the diamond without alteration and then fringed with hydrogen atoms. A similar set of atoms carved out of the graphite flake would do equally well so far as length is concerned, because the graphite layer is, according to Bernal, the diamond layer pressed flat without any sideways extension. But if the carbon atoms were in the supposed graphite condition, it might be expected that naphthalene would be a conductor and opaque like graphite, which is not the case. The direct analysis itself is not yet able to say whether the three attachments of each carbon atom to its neighbors in the same molecule are all on one plane. It is to be remembered that there are attachments between each molecule and its neighbors in the same layer, but these must be far weaker than the bonds binding together the atoms in the same molecule; they are stronger, however, than the end to end attachments which break on the cleaving of the crystal. These last must be feeble because the crystal cleaves so easily.

So far, therefore, the result of the analysis of these crystals is in the first place to give confidence in the existence of a mutual support between the established organic chemistry and the new methods of analysis; and to show us also how closely the behavior of the crystal may be connected with its general structure. As to details, the indication seems to be that the carbon atom has—at least nearly so—the same characteristics as the atom of the diamond; but that one of the four valencies is unused. We have even some grounds for saying that the unused valency, or the unoccupied corner of the carbon tetrahedron is that which lies on the face of the molecule, not on its edge. The crystal of naphthalene tetrachloride, *i.e.*, naphthalene with four added chlorine atoms, shows the same structure as that of naphthalene, and has very

similar dimensions, except that it has broadened by an amount which would correspond closely with the result of adding the chlorines to the places indicated.

Measurements have been made of some of the dimensions of other crystals containing ring molecules, and the results fit in, as far as they go, with the idea that the ring is an actual structure of definite dimension and form, slightly altered it may be by additions or substitutions of other atoms or groups of atoms, or strained because it has to be fitted into its place in the crystal, nevertheless recognizable in its different circumstances, as the chemist would expect. To settle these points more satisfactorily, to turn guesses into certainties is, of course, the work that is before us.

Very interesting results are obtained from the study of the long chain molecules of the fatty acids, hydrocarbons and similar substances. It appears that when these substances in the solid state are pressed onto a flat surface, they form flaky crystals like graphite or naphthalene and it becomes easy to measure the thickness of the monomolecular layer. The experimental results are beautifully definite, and their interpretation can be given with great chance of being correct. It seems that the molecule is perpendicular to the layer, not slanting. If it were the latter, one would expect the amount of slant to be variable so that it would not be possible to connect the thickness of the layer with the length of the molecule only. Now, it is a remarkable fact that the thickness of the layer grows at a uniform rate as the chain is increased by the addition of carbon atoms and that for very nearly all if not all the different kinds of chain molecules that have been examined, this rate has one or other of two values. For every two carbon atoms that are added the increase in length is either 2.50 AU or 2.00 AU very nearly.

If we were to suppose that every carbon atom in the chain had four points on it, disposed like the corners of a regular tetrahedron, at any one of which an attachment could be made to a neighbor, in other words, if we supposed the atom to be as in diamond, then a chain of carbon atoms would take one or other of three forms, A, B, or C, the last of which is a screw. Putting the distance between the center of two carbon atoms equal to the distance found in the diamond, *viz.*, 1.54 AU, it can readily be calculated that the length of chain A is 2.50 AU for every two atoms added, and of chain B, 2.05 AU. The agreement with experiment seems to be more than a coincidence; it is justifiable to assume that in these chains either the A or the B form is adopted, and the linkage of carbon atoms with their neighbors is on the diamond plan. In other words, if PQR is the center of three atoms, the angle PQR is equal to the

angle between two of the lines joining the center of a tetrahedron to the corners.

One of the most striking results is the fact that the length of the main body of the chain is independent of the nature of any additions to its ends or replacement of any of its side hydrogens by an oxygen atom as in the ketones. Even the removal of two or four hydrogens from the body of the chain leaving two carbons connected respectively by a double or a triple bond makes no appreciable difference in the length. It would not have been a matter of surprise if such treatment had caused a bend in the chain, on account of the relative shifting of points of attachment on the carbon atom that might be due to other points of attachment being unused. The removal of a pair of hydrogens from the chain makes no more difference to the chain than the stripping of an opposing pair of leaves from the stem of a plant.

A very curious point in the behavior of the long chains is their apparent doubling in length when one end is formed of a so-called active group, as for example in the case of the fatty acids. When this is the case two chains join end to end, the active groups being together, and again the result is just the same as if two sticks were joined into one, the process of joining being concerned with nothing beyond the two active ends. This form of structure is illustrated in a very interesting way in the X-ray spectra. If a section is made of a substance consisting of layers of these doubled molecules, so as to show their stratification, then there will be a uniform distribution of diffracting centers—electrons—throughout the mass, with alternating thin layers of excess through the active ends and thin layers of deficiency through the inactive ends, the methyl groups. This has the curious effect of intensifying the odd orders of the diffraction spectra. To understand this, it is only necessary to remember that if we were to make a series of fine rulings on a diffraction grating which exactly interleaved the stronger original rulings, the result would be the strengthening of the even orders; such an effect is found in the case of rock salt and was an important help in the determination of its structure. If now the additional rulings, instead of being like the original but weaker, could be of reversed effect, a deficiency instead of an excess, it would be the odd, not the every order that would be strengthened. The same effect is found in the case of the ketones. When the substituted oxygen is in the middle of the chain, each layer of hydrocarbon molecules shows a generally uniform distribution of electrons with an excess at the middle where the oxygen atom is placed and a deficiency at either end. When the substituted oxygen is not in the middle the reinforcement of the odd orders disappears.

These many observations of the behavior of the long chain molecules seem to point to the conclusion that the carbon atom in the chain is, like the carbon atom in the diamond atom, possessed of four points of attachment regularly disposed about it, and that the non-use of one does not alter the disposition of the others.

It is scarcely necessary to consider in any detail the points given by structures like tartaric or succinic acid as to the behavior of carbon atom. It is enough to say that, while the full interpretation is yet to come, the general indications are in accordance with what has already been said.

I have thought it might be of interest to consider these first tentative conclusions as to the behavior of the carbon atom in the solid body, in spite of the fact that so little, relatively, has been accomplished in the solution of the structure of organic crystals. What is to be done must have great consequences, and what little has been done already seems to possess many points of novelty and of interest, and these two facts taken together may be sufficient justification for my attempt at a review of the present position of the inquiry.

THE BEST USE OF THE WATERS OF THE GREAT LAKES

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MAN'S progress is dependent largely upon his development of good transportation, upon his use of mechanical power and upon his success in conquering disease.

If the reader has any doubt as to whether man's progress depends upon transportation let him look at good maps and note the evident relation between well-developed lines of water and railway transportation and the degree of civilization in the vicinity of those routes.

The substitution of mechanical power for the muscles of man and beasts is the basis of our modern industrial system in which each man actually turns out four times as much useful production as would otherwise be possible.[1]

Man's conquest over germ-borne disease has reopened the tropics to the conquest of the white man. In the days of poor sanitation cities were the homes of diseases. To-day a man has a better chance of long life, thorough physical development and freedom from disease in the cities than he has in the country.

We should develop transportation, cheap power and sanitation to the best of our ability. The waters of the Great Lakes may be made to help greatly in all three of these things.

Formerly many engineers believed that their help should be limited to the technical side in supplying transportation, power and sanitation. Now engineers believe that it is a part of their work in the world to help in the promotion, the advance work, the educational work, involved in these three things. I certainly believe strongly in that idea.

There are the Great Lakes. There is a drop of 21 feet between Lake Superior and Lake Huron, which is mainly in the rapids at the Sault locks. Note on the chart the elevations above sea level in feet marked on each of the lakes. Lake Michigan and Lake Huron together form one lake, all at elevation 581 feet above sea level. There is a drop of only 8 feet from Lake Huron to Lake Erie. There is a drop of 327 feet from Lake Erie to Lake Ontario, of which but little more than one half is in Niagara Falls. The

[1] "The Discovery of Truth in Universities," by Walter Dill Scott, p. 6.

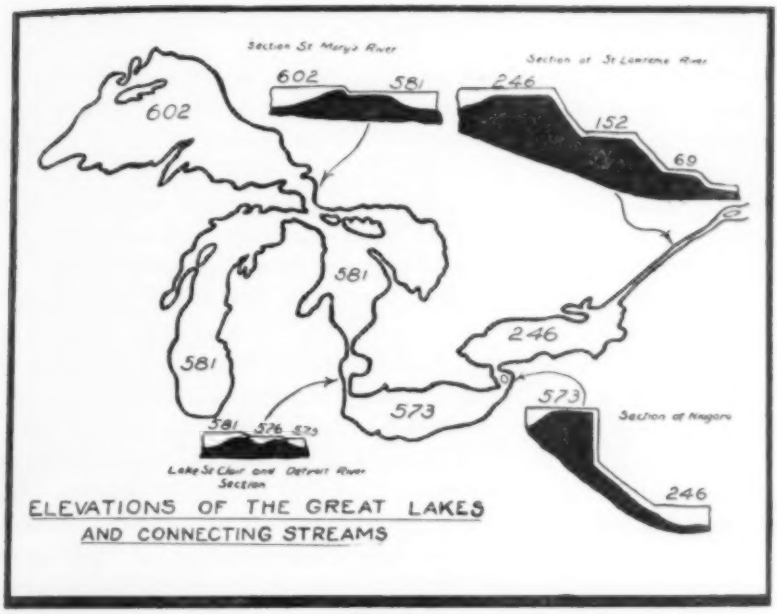

FIG. 1

drop from Lake Ontario to the ocean is 246 feet, which occurs mainly in three series of rapids between Lake Ontario and Montreal as shown here.

Any plan for the best use of the waters of the Great Lakes must be placed upon a consideration of the Chicago Sanitary District diversion problem, of the depth of water now available and that which will be needed later in the harbors of the Great Lakes and in channels connecting the Great Lakes, of the development of power at Niagara, and of the St. Lawrence project for improving navigation and developing more power.

The problem of securing the best use of the waters of the Great Lakes involves directly and strongly the interests of at least 18 states, where more than one half the population of the United States reside. Similarly it involves the interests of Southeastern Canada.

The Great Lakes and their connecting streams furnish the opportunity for the greatest development of inland water navigation possible anywhere in the world. In fact the inland navigation already developed on the Great Lakes and connecting streams is greater than anywhere else in the world. Yet the development of inland navigation on the Great Lakes is not nearly up to the possibilities.

More tons of freight pass Detroit in an open season of eight months than pass through both the Suez and Panama Canals in

three years.[2] No set of canal locks anywhere in the world carries nearly so much traffic as the locks of Sault Ste. Marie.

The Great Lakes and connecting streams, including the St. Lawrence River, are the most thoroughly studied bodies of water in the world. For example, careful continuous records of the elevations of the water surface of the Great Lakes have been secured from 1860 to date. The Niagara River has been gauged more than 300 times. The flow is known within 1 per cent. These unusually thorough studies enable one to plan improvements with confidence.

In order to secure the best use of the waters of the Great Lakes for the benefit of man six things should be done: (1) Carry out the St. Lawrence project; (2) Take out ten thousand cubic feet of water per second at Chicago, through the Drainage Canal, and use it well for sanitation purposes; (3) Build dams with movable parts at Buffalo and in the St. Lawrence River and use them wisely to regulate the levels of the Great Lakes; (4) Build a submerged dam at Niagara Falls to prevent the backward travel of the falls and the wasting of water where it does no good either for scenic purposes or for power; (5) Utilize the whole drop of 300 feet from Lake Erie to Lake Ontario for developing water power—as soon as is feasible; (6) Utilize the power opportunities on the St. Lawrence to the full, as rapidly as the market for the power can be developed.

What is the St. Lawrence project? What is its present status? In 1920 under the provisions of a treaty of 1909 between the United States and Canada, relating to the boundary waters, the International Joint Commission was asked "to investigate what further improvement of the St. Lawrence River between Montreal and Lake Ontario is necessary to make the river navigable for ocean-going vessels, together with the estimated cost thereof."

In 1921 the International Joint Commission, three men from the United States and three from Canada, reported back to the two countries. The main points of their report are as follows:

(a) That the Governments of the United States and Canada enter into an arrangement by way of treaty for a scheme of improvement between Montreal and Lake Ontario.

(b) That the proposed works between Montreal and Lake Ontario be based upon the report of the Engineering Board to the International Joint Commission, but that before any final decision is made that the Engineering Board report be referred back to an enlarged Engineering Board for a further more complete study. This Engineering Board report referred to certain specific dams and canals with locks for the improvement of navigation and certain power houses for the development of hydro-electric power.

[2] See the "Warren Report on Diversion of Water from the Great Lakes and Niagara River," p. 393.

(c) That the New Welland Ship Canal now under construction by the Canadian government be embodied in the scheme of improvement, and treated as a part thereof.

(d) That such navigation works as do not lie wholly within one country or are not capable of economic and efficient construction, maintenance and operation within one country, be maintained and operated by a board to be called the International Board, on which each country shall have equal representation, and that such navigation works as lie wholly within one country are to be maintained and operated by that country with the right of inspection by the International Board just referred to.

(e) That power works be built, installed and operated by and at the expense of the country in which they are located.

(f) That the cost of the navigation works be apportioned between the two countries on the basis of the benefits which each will receive from the new waterway; that the ratio of the benefits be determined in a certain way during the period ending five years after the completion of the works; and that the ratio shall be readjusted each five years, based upon the freight tonage of each country actually using the waterway during the previous five year period.

It is to be noted that this report of the International Joint Commission is primarily a suggested plan of procedure which should be incorporated in a treaty. It is also an approval of the general report of the engineering board with the suggestion that before actual construction is undertaken there should be further investigation.

The New Welland Canal, from Lake Erie to Lake Ontario, which is adopted as a part of the St. Lawrence project, is now under construction by the Canadian government. The total cost will be more than 50 million dollars. It includes locks with a depth of thirty feet and a canal with a depth of twenty-five feet which can easily be increased to thirty.[3]

The new construction on the St. Lawrence as reported by the engineering board includes thirty-three miles of canals with the necessary locks for navigating past the various rapids in the St. Lawrence—two large dams—and all the other miscellaneous construction necessary for the operation of the dams, locks and canals. It also includes the power houses and auxiliaries for developing 1,400,000 horse power. The navigation works, dams, etc., are to be so constructed as to make the ultimate development of an additional 2,700,000 horse power possible. It is not, however, proposed to make this expenditure to develop the 2,700,000 immediately, because it will take many years, possibly a generation, to develop the market for that amount of power. The construction is intended to keep step with the development of the market.

[3] Report of International Joint Commission on the St. Lawrence Waterway, 1922, p. 24.

At present the navigation along the St. Lawrence is limited to ships which can be operated in a depth of 14 feet. When this project as proposed is carried through the depth in all canals will be 25 feet and for an additional $17,000,000 it can at any time be increased to 30 feet. A depth of 25 feet will provide for the bulk of the ships now carrying freight on the ocean.

The total cost for the navigation works and the development of 1,400,000 horse power will be $250,000,000. The Panama Canal cost the United States about $400,000,000. As already stated more traffic now passes Detroit in each open season of eight months than goes through the Panama and Suez Canals combined, in three years.

The Panama Canal was built as a military necessity, to unite our Atlantic and Pacific fleets into one fighting unit. It passes a few commercial vessels each day from ocean to ocean—about 8 each way per day—serving the people of all the world. The Panama Canal is abundantly worth while.

For a much smaller cost—250 instead of 400 million—we may get an improved St. Lawrence-Great Lakes channel carrying several times as much ocean traffic as the Panama Canal and have power plants for developing 1,400,000 horse power thrown in. The benefits will be concentrated largely on 60 million of the people of the United States and Canada.

1,400,000 horse power at prevailing rates is worth $180,000,000 per year.[4] The total horse power developed at present in the United States from water is only about 9 million.[5] This one project would add 1/7 to this total development.

Electrical power can be transmitted with reasonable economy for about 300 miles. The 300 miles radius from the proposed development near the Long Sault rapids in the St. Lawrence includes all of New England and all of New York state and a still larger area on the Canadian side.

The present status of the matter is that the enlarged engineering board for further investigation has been provided for and a St. Lawrence Commission has been appointed by President Coolidge to meet with a similar commission to be appointed in Canada.

There is no doubt about the feasibility of the project, nor about the great benefits to be derived from it. As I understand it, the

[4] 1,400,000 horse power = 1,000,000 kilowatts. At 2 cents per kilowatt hour, one kilowatt year is worth (2c) (24) (365) = $180 per year and one million kilowatts is worth $180,000,000.

[5] *The Electrical Review*, June 5, 1920, p. 940, in an article entitled "Development of national water river resources," shows that in 1915 the U. S. Geological Survey estimate was 8,609,000 developed H. P. from water in the U. S. out of a potential maximum of 63,490,000 H. P.

questions to be immediately attacked are what part of the projects shall be taken up at once and what is the general plan which should be incorporated in the treaty?

The logic of the facts is so clear that the main question is how quickly and how successfully may the people of the United States and Canada be made to see the truth and how soon, therefore, will they eliminate their differences and get together in this work, which is the main part of the greatest opportunity now open for benefiting the peoples of the two countries.

The second of the six things which I stated should be done to secure the best use of the waters of the Great Lakes is to take out ten thousand cubic feet of water per second at Chicago through the drainage canal and use it well for sanitary purposes.

In the 90's Chicago secured permission to dig the drainage canal. It constructed the drainage canal in good faith. In so doing and in constructing the other works necessary to utilize the canal fully it has spent $100,000,000. It is now taking out of the lake nearly 10,000 cubic feet per second and has been doing so for years. It is using that water to dilute its sewage and to carry it away from Lake Michigan—away from the source from which Chicago draws its water supply. In doing so it has lowered the levels of Lake Michigan, Lake Huron and Lake Erie nearly half a foot, and has thereby caused damage to navigation. An attempt is now in progress, and has been for some time, to cut down the supply allowed to Chicago to but little more than 4,000 cubic feet per second.

Why should Chicago take out 10,000 cubic feet per second? It has made an investment of $100,000,000 in good faith on that basis, on the supposition that it will be allowed to continue to take out that amount continuously. The size of the drainage canal and the whole sewage system in connection with it is based on that assumed discharge.

The population of Chicago has already grown beyond the limit at which it is possible to dilute the sewage sufficiently—with 10,000 cubic feet of water per second—to keep it from being a nuisance. Some of the sewage, therefore, is now being treated before going into the drainage canal. The plans of the sanitary district provide for additional treatment plants on a program of construction reaching to 1945 which involves the expenditure of about 4 million per year (a total of 95 million). If the diversion at Chicago is cut below 10,000 cubic feet per second, say to 4,000 cubic feet per second, there will be an increase of millions per year in the necessary expenditure for sewage treatment—how many millions has never been carefully estimated so far as I know.

There is, however, a still more urgent reason for keeping the diversion up to 10,000 cubic feet per second. Even when 10,000 cubic feet per second are taken out the current in the Chicago River near its mouth reverses about once each year, either because of a sudden drop in the lake level—possibly as much as a foot—or because an excessively heavy rainfall occurs which reverses the flow. If the diversion is only 4,000 cubic feet per second—with a slow current through the drainage canal—the Chicago River will be reversed on an average seven or eight times per year. At the time of each reversal there is a probability of the occurrence of typhoid and other intestinal diseases. If there were seven or eight reversals per year of the character that would occur with 4,000 cubic feet per second there is a certainty of occasional typhoid epidemics even with the best that can be done with dosing of the water with chlorine.

It is clear that Chicago should take out 10,000 cubic feet per second in order to keep its expenditures for additional sewage treatment plants within reasonable limits and in order to prevent the typhoid epidemics which must occur if there are frequent reversals of the current.

There may be some doubt as to the legal status of the matter. There can be no reasonable doubt as to the equity. Chicago secured in the 90's what was then believed to be the only permission required. It has constructed and used a one hundred-million dollar plant based upon the drainage canal and the use of 10,000 cubic feet per second. It has thereby saved many thousands of lives. There is no adequate substitute available in a reasonable time for the 10,000 cubic feet per second and the drainage canal. There is no possibility in any length of time of a substitute which will not cost much more than these two things. That statement is true even if Chicago pays for the regulating dams which have been proposed, and for which the sanitary district has offered to pay.

Chicago has lowered Lake Michigan, Lake Huron and Lake Erie by nearly half a foot. The most serious damage to navigation thereby produced has been the reduction in depth in the channel on the St. Clair flats above Detroit. For every tenth of a foot added to the depth there the largest vessels can each carry about 76 additional tons of freight at no extra cost. For the actual fleet of big ships operating past this point the additional revenue which they could so secure would be about $600,000 per year for each tenth of a foot added to the depth.[6] For two and one half to eight

[6] "The J. G. Warren Report on Diversion of Water from the Great Lakes and Niagara River," pp. 388–90.

million dollars two regulating dams could be built, one at Buffalo where the Niagara River leaves Lake Erie and one in the St. Lawrence (as a part of the St. Lawrence project). These dams properly operated would restore the depth lost by Chicago's diversion of 10,000 cubic feet per second—and more—would put the lakes at a higher level during the dry years than they would be in a state of nature, and would not put the lake levels above the danger limit in flood years.

The dam at Buffalo would raise Lake Erie first. The back water effect would then raise Lake Huron and Lake Michigan. The fall is less than nine feet from Lake Huron to Lake Erie—and nothing between Lake Michigan and Lake Huron. Clearly these two regulating dams should be built and operated. They would bring a benefit to navigation which would be a return over and above the cost of operation of 50 per cent. to 100 per cent. per year on the investment. The return would be at least three millions per year if the average depth over the St. Clair flats were increased by a half foot upon an average.

There is a strong sentiment in favor of preserving Niagara Falls as a great scenic asset to the United States. That sentiment is good. At present it prevents the use by the United States and Canada of much more than about one fourth of the water which goes down the Niagara River. Meanwhile Niagara Falls is slowly receding—wearing away. We should apply our sentiment sensibly. We should hold to the scenic value. We should prevent the wearing away and we should develop more power at Niagara. The value of the power now thrown away for the sake of the scenic value amounts to about $1 per minute for each person looking at the falls.

About one half of the water which now goes over the falls disappears in the angle of the Canadian falls,[7] where it contributes but little to the scenic value because it can not be clearly seen, and where it does much work in wearing away the falls. At the most serious point the edge of the falls is moving back about five feet per year. There is little wearing away at any other part of the falls. The scenic value at Niagara Falls comes mainly from the thin sheets of water running over the edge of the rocks at other places than this partially concealed notch—and from the rapidly moving water near the shores. We should build a submerged diversion dam to protect the notch in the Canadian falls, prevent the recession of the falls, divert the water in part to the other portions of the falls where it can be seen as it drops over and hold back a large amount of water which could then be used in the power plants.

[7] "Diversion," p. 275.

The falls would then be as beautiful, or more so, than they are now. They would be more permanent, and we could develop 50 millions of dollars worth of power per year at Niagara more than is now being developed.

You ordinarily think in connection with Niagara of the drop of 170 feet in the falls and forget that that is only about half of the total drop of 327 feet from Lake Erie to Lake Ontario. The present power plants are utilizing only the drop at and near the falls. Some of the present power plants are using that part very inefficiently. A Canadian plant is now being built which will use nearly the whole 300 feet of drop from Chippewa above the falls to Lake Ontario. Something corresponding to this should be done for all the water used for power. This scheme, combined with that of the submerged dam and with power plants rebuilt in some cases to secure high efficiency, would multiply the power development at Niagara by about four.

The sixth thing that I have suggested is that the additional 2,700,000 horse power postponed for future development, according to the present St. Lawrence project, should be developed as rapidly as the market for that power can be secured.

To summarize, to secure the best use of the waters of the Great Lakes for the benefit of man six things should be done: (1) carry out the St. Lawrence project, (2) take out 10,000 cubic feet per second at Chicago and use it well for sanitation, (3) build dams with movable parts at Buffalo and in the St. Lawrence River, and use them wisely to regulate the levels of the Great Lakes, (4) build a submerged dam at Niagara Falls to prevent the backward travel of the falls and the wasting of the water where it does no good, either for scenic purposes or for power, (5) utilize the full 300 foot drop from Lake Erie to Lake Ontario for developing water power instead of a half only, (6) utilize the power opportunities in the St. Lawrence to the full, as rapidly as the market for power can be developed.

Some miscellaneous comments are now in order. A large increase in the transportation facilities from the Great Lakes to the open Atlantic would do much to avoid future railroad congestion and embargoes. This is important.

The same additional transportation facilities as it is proposed to provide by the suggested improvements on the Great Lakes and St. Lawrence could not be secured by additional railroads and railroad terminals except at a very much higher cost.

Some ocean-going vessels can not navigate in a channel of 25 feet of depth. But the ships which carry most of the freight by

ocean can and would navigate such a channel. The freight of the world is not carried in ocean monsters. It is carried in ships of moderate size.

Locks are not a serious impediment to the progress of large vessels. The locks at the Sault and at Panama are a positive proof of this.

It has been a contention that Chicago should not take out water from Lake Michigan because it reduces the possible power development at Niagara. The reader will get a true view of this argument, if his sense of humor is in good order, when he considers that the diversion at Chicago, 10,000 cubic feet per second, is only 5 per cent. as large as the ordinary flow at Niagara, over 200,000 cubic feet per second.

The chance to use the waters of the Great Lakes in the best way for sanitation, navigation and power is the greatest opportunity to do a good service that is now open to the peoples of the United States and Canada. There are no serious uncertainties involved in the plans proposed. The time which elapses from now until that best use is made is a measure of the degree of intelligence of the American and Canadian peoples—and of the abilities of their governments.

The two nations, Canada and the United States, and the three interests, navigation, power and sanitation, should eliminate their differences and pull together in this work for the benefit of all.

POPULATION AND PROGRESS

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To appreciate the consequences of the expansion of populations, it is necessary to develop historical perspective. We may visualize the growth of humanity as beginning with small streams of population in the more favored regions of southern Asia and Europe. From the plains and river valleys first inhabited, the tide flowed over into adjacent areas until all the continents were occupied. In some of the less favored regions populations remained quiescent without material increase or decrease. But in the more favored regions numbers grew rapidly, and poured out in floods of immigration and conquest over neighboring lands. The stress of the resulting competition and conflict weeded out the inferiors and promoted ability. This process of growth, expansion and the establishment of new levels of capacity has been repeated from prehistoric times to the present. We are in fact to-day in the later stages of the greatest population expansion that has ever occurred.

I. The Law of Population Increase

The increase of population is measured simply by the difference between the birth-rate and death-rate. Leaving out of account for the moment the question of migration, we may call attention to the forces which for long intervals of time have produced a relative balance between the two rates. It is obvious both from theory and experience that a virile population living under continuously favorable economic conditions will increase at a geometric rate; that is, it will double in a definite interval ranging from 25 to 50 years. The enormous potentialities of such a rate of increase are not apparent on the surface, and may be emphasized by the following calculation. If we assume the very low rate required to double a population in 100 years, that is, an average family of only two or three surviving normal children, then the six thousand years of human history would have been sufficient to give a present population of more than a billion times that now existing. Obviously the natural tendency to increase soon gives a surplus population in any favorable land area. When the surplus has become large, the lower classes are inevitably forced into poverty, even though agriculture may be intelligently managed and the distribution of wealth may be equitable. With poverty come vice and pestilence as nat-

ural consequences; and war is indirectly fostered by the same conditions. Eventually the death-rate approximately balances the birth-rate and the population becomes relatively stationary in numbers. This is the well-known theory of Malthus, which is admittedly true of earlier nations. Its applicability to present conditions may be deferred for later consideration.

It is important to recognize the social conditions growing out of the increase of numbers and determining the structure of typical ancient nations. Put in economic terms, the growing pressure of population in a hitherto uncrowded land area caused wages to fall, and land values and the cost of living to rise. Consequently, the position of the laborer and small land-owner was depressed, and the position of the large property holder was correspondingly enhanced. To be sure, in earlier times neither wages, products nor land values were measured at all accurately, but the conditions thus described in economic terms were apparent in the fact that life was cheap and the possession of good land was greatly desired. Out of such conditions arose land-holding aristocracies, defending their privileges with the sword, or relieving the pent-up energies of the nation in attacks upon neighboring peoples. Naturally the outcome of population pressure can hardly be described in a single phrase, since many circumstances have conspired to modify the particular event. Sometimes relief was temporarily found in migrations and trade, sometimes extended class struggles developed, sometimes militaristic aggression built up extensive empires. But whatever the details, eventually out of the ruck appeared established privileged orders on the one hand, and a dull and spiritless peasant or slave population on the other.

We may next briefly examine the conditions obtaining during a period of population growth. As may readily be seen, such a period is initiated by the opening of new territory or by some notable advance of invention, or by a combination of the two. Historical illustrations are the transition from barbaric to pastoral, and from pastoral to agricultural life, or the trade expansion of the ancient Greeks, the medieval Italians and the modern English. Such periods have usually brought strong democratizing tendencies. New methods of production and the growth of trade and cities have raised the status of the masses and offered opportunity to the capable. Hence the latent ability of the repressed lowly has made its influence felt, and a marked swing toward individualism and democracy has been experienced. It is perhaps not too much to say that economic expansion and democracy are causally interrelated.

Whenever a rising level of the industrial arts has thus allowed numbers to increase, it has generally been accompanied or followed by an overflow into neighboring territories through trade, colonization and conquest. This process is entirely natural, since progress brings both power and prestige, and makes backward areas appear by contrast to be sparsely settled. If the difference in culture is very great, the higher civilization in its expansion may sweep aside the lower civilization, just as the Indians were driven back before the advance of the American frontier. But if the difference is small, the process may be that of economic penetration, bringing with it usually a more or less acknowledged political dependence. Under earlier conditions such economic expansion merged with the militaristic aggressions already referred to, and even in modern times force has not been entirely absent.

While the conscience of the modern world has reacted against the cruder phases of the processes of expansion, it should be observed that progress has nevertheless been served thereby. Though attended with much waste and injustice, ancient imperialism such as that which Roman history recalls was a notable agent in the extension of civilization. Great areas of barbarism were turned from low production and tribal feuds into advanced production and the reign of law. And even when civilization fell, the incursions of barbarian tribes into the centers of a weakening culture brought infusions of new and virile blood, making possible a renewed advance. In spite of the wastes of such conflict, seldom was a civilization lost, while usually it was promoted and extended.

A bird's-eye view of the course of history with its short periods of advancing prosperity and its long centuries of relative stagnation raises the perplexing question why progress has not been more constant. Why has each advancing wave of culture been thrown back from its highest point of advance? No easy answer to this question is obtainable. Attention may, of course, be directed to this or that element of weakness in each social system. Sometimes the ruling class became simply exploiters rather than administrators. Sometimes natural resources were exhausted, or changes in climate diminished the fertility of the soil. But however unfavorable the environment may have been, the chief defect evidently lay in the dearth of men of ability and energy to cope with it. This defect was the consequence, so the biologists say, of a reversal of the workings of natural selection. Under cruder conditions society grew faster in the upper ranks, and the younger sons of the virile nobility, recruiting the ranks of the commoners, graded up the general level, while high death-rates weeded out the weaklings. But often in advanced

civilization this process has been reversed. The competition for preferment, the lure of luxury and the encroachments of vice have checked the increase of the more capable elements of the population, while the inferior have bred freely. Consequently, it is said, the level of ability has been lowered, the discipline of able leadership lost and civilization has fallen back to a lower level where natural selection was again brought into play.

II. The Modern Expansion of Civilization

Beginning approximately with the time of Columbus, the modern age is an example on a large scale of a dynamic tidal wave of progress, following in many particulars the precedents of the past. In the fourteenth and fifteenth centuries, there was little to indicate the vast proportions that this movement has assumed or the direction that it would take. Up to that time there had been little real advance of civilization since the Roman expansion; and some of the principal methods of production in agriculture, textiles and metals were but little beyond prehistoric antecedents. What is more, the level of European civilization was not materially above that found in the much greater areas and populations of Asia. In preceding centuries, Europe had with difficulty repelled the repeated attacks of the then higher civilization of the Mohammedans and had virtually failed in the exhaustive counter-attacks of the Crusades. The wealth and culture of the Indies and the Orient were still the magnets to which Europe was attracted. A Marco Polo of that era looking dispassionately upon the people and resources of the world would most likely have considered Asia the permanent center of world civilization. With what incredulity would he have greeted a prophecy of modern Europe or of the overshadowing New World of to-day! Yet it is the unprecedented geographic and cultural expansion of the white race that forms the theme of modern history and that has moulded the institutions and traditions of the modern age. Only recently has the great advance reached its farthermost barriers.

Looked at from the standpoint of territory, the white races have expanded from their obscure European position in medieval times to a point of world domination. According to Mr. Stoddard's estimates, of the fifty-three million square miles of habitable land on the globe, forty-seven million are either populated by the white race or are under white political control. In fact, about a quarter of the earth's surface and population is comprised within the British Empire alone. Of the 1,750 million inhabitants of the globe, 650 million, or 37 per cent., are white of European origin, while another sixty million, or 4 per cent., are white of non-European origin.

The next race in point of numbers is the yellow with 510 million, or 29 per cent. The brown race comes third with a population of 420 million, or 24 per cent.; while the black race comes last with a population of 110 million, or about 6 per cent. While Asia on account of its great size still has a bare majority of the world's population, it has utterly lost its place in respect to culture and progress.

The position gained by the white race is rendered more secure by the immense resources of the new lands which it has acquired. The greatest areas of arable land outside the tropics are Europe, North America and southern and eastern Asia. If we include smaller areas in South America, Africa and Australia, the arable land of the white race will be found to surpass that of the yellow and brown races combined by nearly two to one. When the comparison is made in terms of the physical basis of industrial power the contrast is still more striking, since the United States alone has probably half of the world's coal and iron reserves, together with immense resources in other minerals. In respect to climate, also, the white race possesses a great advantage. The climatic conditions of Europe and the United States are preeminently of the kind that awakens and sustains human energies.

And not only has the white race gained a dominant world position, but its relative power increases from year to year. Professor East estimates that the white race of European origin is increasing on a prewar basis at an average rate of nearly eight million a year, which is about 60 per cent. of the total increase of the world's population. Its nearest competitor, the yellow race, is increasing by only one and one half million a year. To put it another way, the white race is doubling in a period of 58 years, while the yellow race at its present rate of increase requires 232 years to double. The black race is increasing a little faster than the yellow, but its numbers are relatively so small that its growth is insignificant. Added to the ascendancy of territory and numbers, the white race has acquired such an enormous lead in scientific and industrial development, in social organization and in the general education of its masses that its power is greatly multiplied. Thus the period of European expansion which began with Columbus and which swelled to such immense proportions in the nineteenth century has already carried the white race to the point of secure world domination in respect to power and prestige, and is still carrying it forward with a momentum that far surpasses the rate of progress of the other races of the world. Nor has the World War changed the situation materially, the rates of increase in the more advanced countries having reverted to prewar figures almost immediately after the close of the conflict.

The interracial comparisons which we have just made seem to indicate that the so-called yellow peril is an exaggeration and that, in fact, the backward races might more logically speak of a white peril. There is, nevertheless, something to be said in regard to the increasing resistance which the backward races are beginning to offer to white exploitation. This increasing resistance is not, however, a reaction to wrongs that have been suffered at the hands of the white race, as some would have us believe. In spite of many regrettable incidents, white expansion has been more beneficent to the populations it has overrun than has ever been true of corresponding movements before. Except in a few minor instances, it has conferred on the backward peoples far more than it has taken from them. On account of its great cultural achievements, it has everywhere brought industrial improvement, suppression of disease, higher knowledge and superior laws and ethics. If there is a yellow peril or race peril at all, it is the result of the increasing ambition and power which the new civilization has stimulated in the backward races.

A brief survey of the situation in the Orient will be sufficient to set forth the case. The population status of Asia has historically been established by a great overcrowding which has balanced an exceedingly high death-rate against a correspondingly high birth-rate. With the coming of modern methods of sanitation and the improvement in means of production and transportation, the death-rate is being temporarily lowered. But, on the other hand, the birth-rate is entrenched in ancient customs and religious beliefs which give way but slowly before the advance of the new civilization. As a consequence, population increases so quickly that little benefit is derived from improvements in production such as have been brought about by British engineers in Egypt and India and by the newly educated leadership of Japan. India, for example, has increased from 178 million to 332 million, or 30 per cent., in half a century. This population is about six times as dense as that of the United States and is almost wholly agricultural. As a consequence of such overcrowded numbers, the rate of increase is now checked at less than one tenth that prevailing in the United States and Europe, although the birth-rate is twice as high. At the same time the mass of the population is inevitably held down to standards of living that are incredibly low from our point of view, but which can never be raised as long as the present population tendency lasts. Of all the Orient Japan has experienced the greatest benefit from the influence of western civilization. As a result its overcrowded population has already shown a rate of increase equal to that of Europe, although

the per capita income is less than 10 per cent. of that of the United States.

Oriental peoples, therefore, numbering about half of the population of the globe, are repressed by overcrowding to a degree that we can hardly comprehend, and the benefits of modern scientific production and sanitation mean very little to them except by way of awakening ambitions that only a few can attain. It is but natural, therefore, that they should look with envy on the sparsely populated areas of Australia and America and consider the white man's policy of exclusion unfair. Wherever they can find a foothold they will do so, and with their low standards and habits of industry will displace other populations. Potentially their hundreds of millions might become billions if land were available, but now that the white world has put up the immigration bars it is not available. Their own lands can not be made the basis of a much greater food supply than at present. While they may find room for some expansion into Northern Asia, they are not at all likely to increase to a point where they could menace the white race in direct conflict, though they may be an important factor as an ally to one or another of the competing elements of the white race. The principal cleavages of the future will doubtless still be divergent white civilizations against each other, as in the past. A Teutonic-Slavic alliance, for example, might find Oriental allies. But the cleavages of the Orient are as deep as those of the Occident, and a united East is an improbability. The yellow peril, in as far as it exists, is chiefly the menace to high standards that is inherent in low standards, a menace which is not limited to alien races. It holds no alarming threat to the white world except under the now abandoned policy of unrestricted immigration.

III. Diminishing Returns

It is popularly assumed that the industrial progress which has characterized the nineteenth century will continue indefinitely and that therefore social standards will continue to advance. Many students of world affairs, however, hold a contrary view. Briefly stated, they consider that the present era of progress has resulted from the vast new lands that have been made available, and that the relative disappearance of poverty and the rise of democracy are merely incidents of this expansion. They assume, therefore, that with the inevitable return of population pressure, labor will be cheapened and society will again revert to mass poverty, militarism and authoritative government by privileged classes. That is, they assume the Malthusian theory to be strictly applicable to the case. And when the pertinent data are examined it will be found that this view is at least worthy of consideration. We shall then briefly

review the arguments usually cited in support of the theory that population pressure and its attendant social conditions are returning

At first thought, the history of invention and business progress during the last century or two certainly gives the impression that permanent progress is now assured. During almost all this period of time right down to the present, wealth and income have been increasing faster than population, at least in the more advanced portions of the world. It would seem, therefore, that in view of the possible further achievements of science no shortage of production is in sight. The optimist points to the so-called miracles of science: to power machinery, to the conquest of distance and finally to the achievements of scientific agriculture. In view of increased wealth and the abundance of food he laughs at the possibility of coming scarcity.

But on further consideration much of this exuberant optimism will be found to be mere rhetoric. The fact is that the achievements of science are not primarily of the sort as yet that will alleviate the increasing demand for food in overcrowded areas. What science has done is to render possible the extensive cultivation of new lands rather than to increase materially the production per acre. As a result, the populations of Europe are to-day in a large measure dependent upon newer regions for the food supplies which they purchase with the products of their factories. It is true that European agriculture has also made great advances because of proximity to the primary markets. But in spite of this progress, the United Kingdom depends upon the outside world for over 50 per cent. of its food, while Germany, France, Belgium, Italy and Holland, in the order named, are also dependent upon food importations. The same may be said of Sweden and Norway, although these countries could be practically self-supporting if necessary.

The chief sources upon which Europe depends for its food supply are, on a prewar basis, Russia, the United States, Canada, Argentina, India and Australia. As long as these countries continue to export large surpluses of food and to import manufactured products, Europe can maintain its present population. But in the main the food-producing countries just mentioned are rapidly progressing to a point where they will produce much of their own manufactures and consume the bulk of their food products. This is particularly the case with the United States, where the exportation of foodstuffs is now overshadowed by the exportation of manufactures and manufacturing materials, the proportion in 1921 being 260 per cent. The United States is, therefore, more of a manufacturing rival of Europe than an agricultural support. Australia and Canada and to a lesser extent Argentina, with their rapid increase

in population, bid fair to approach the same situation within a generation or two. Russia will eventually move in the same direction and will have an enormous population of its own to feed. Even India may some day gain its economic independence or become tributary to Asiatic powers.

But it will be argued that the increasing demand will be met by a more intensive agriculture and a consequent greatly increased yield per acre. There is, doubtless, considerable room for improvement in this respect but not as much as is usually assumed. The possibility is confused by viewing it in the light of the increased agricultural production per laborer which has resulted from the use of cheap lands. But the fact that we have increased agricultural production per laborer tenfold has little bearing upon the problem. This gain having been dependent upon new and cheap land is necessarily transient. Science has not yet demonstrated that it can increase the yield per acre in anything like the degree that it has increased wealth as a whole. The United States, for example, with all its use of agricultural machinery, produces little more than two thirds of the average yield that Japan gets with its semi-medieval methods. Even Belgium, which holds the world's record for intensive scientific agriculture, can barely double our record, and this only with the aid of several times our outlay of labor per acre. Such a comparison clearly indicates that intensive agriculture, even with the use of the most scientific methods, can not increase food proportionate to the recent rate of increase in population. And production thus increased, though it will bring larger returns to capital, will necessarily mean lower incomes and standards for the masses who live chiefly by their toil. Diminishing returns and cheapening labor inevitably go together.

In view of the world's agricultural outlook, it may plausibly be argued that population pressure is already in evidence. Thompson estimates that the close of the nineteenth century brought the beginnings of diminishing returns to American agriculture; that is, the former lowering costs of expanding agricultural production began to give way to rising costs. This, of course, would naturally be anticipated with the disappearance of high grade free land. It is also argued that the disappearance of the frontier has already made itself felt upon the status of the laborer. Wage data in the United States do in fact show a cessation of the former rapid rise in the purchasing power of wages, there having been little or no permanent increase from about nineteen hundred up to the World War. As to Europe, it is said that the condition of the masses has in recent decades shown a more unfavorable trend except as it has been relieved by the favors of social legislation. It has also been pointed

out that the widespread popular discontent evidenced by radical agitation has in turn driven the aristocracies of Europe to make extraordinary efforts for the capture of foreign markets. Under such circumstances, the militaristic attitude has naturally been fostered.

A significant change which is attending the approach of overcrowding is a gradual lowering of the birth-rate, although this change has not thus far produced conspicuous results on account of a similar decline in the death-rate. Biologists have recently been pointing out that the decline of the birth-rate is differential as between superior and inferior stocks and that the numbers of the incapable threaten to swamp the more capable. Many followers of Malthus are inclined, however, to look upon the change in a more favorable light. They consider that the checking of increase is desirable, and while they deplore the present dysgenic trend, they regard it as temporary. In their view it is incidental to the extreme competition for higher social rank that goes on in an expanding civilization—a competition which generally results in late marriages and small families among those who are achieving success. But it is pointed out that as wealth becomes hereditary with those stocks which have proved their worth, family pride is developed and the size of the family tends to become normal again. Though the birth-rate among the established wealthier classes may remain a little below the general average it will doubtless be compensated for by a low death-rate. It is also argued that the present rapid increase of incompetents can not go much further since it must necessarily be checked by increasing poverty and hardship, unless remedied by more positive measures. And though the future may see a large class of inferior and low-paid workers, we are reminded that such a population can profitably be used in the routine labor of modern machine production. Hence the Malthusian is likely to consider that, if prospective wars are not too disastrous, society will at length find stability under the new conditions. The upper classes, being the descendants of those who have proved their worth in the long competitive struggle of the epoch of expansion, may be counted on to rule with wisdom, while the inferior multitudes, after they have become accustomed to low standards and obedience, will find the peace and order of the new era advantageous.

IV. The Outlook

How shall we evaluate the outlook that the modern Malthusian presents? Is it simply the product of the exaggerated ideas and fears that have come with the disillusionment of the World War, or is it a well-founded forecast of the trend of world affairs?

The opinion of the writer is that as far as any definite prediction goes, the Malthusian theory will prove to be misleading. Predicting the future by the past is too mechanical a method of prophecy to be minutely reliable. While it is true that physical causes will produce uniform physical results, it is not true that human reactions to natural conditions will be the same to-day as in the past. It might be predicted, for example, on the basis of ancient experience that modern Europe would pass through a cycle of wars, finding equilibrium at length in the unquestioned supremacy of some military power. And it must be admitted that the recent war and present conditions suggest altogether too strongly the possibility of such a solution. But, on the other hand, new ideals and aspirations have been awakened in the modern world which make such an outcome improbable. It was the moral imponderables in the recent war which finally determined the course of events. However impracticable idealism may be, and however much of illusion it may cherish, it is nevertheless a force to be reckoned with. Hence the easy conclusion that the coming pressure of population will throw the world back to older types of aristocracies is very questionable. Some tempering of the extremes and crudities of democracy there may be, but the precise course of events will very likely proceed upon lines which can not now be anticipated, because the advance of science will bring new instrumentalities into play.

Even as it stands to-day, there are several forces at work which will serve to counteract the results of natural increase. One of these in particular many followers of Malthus have strongly emphasized; namely, the artificial restriction of population. Unfortunately, their propaganda has been largely responsible for the dysgenic effects already alluded to. Furthermore, it arouses a strong moral opposition and is especially repugnant to the more virile populations who aggressively seek to further their class or national interests. Hence it is not at all likely to prove the cure-all for social ills that the Neo-Malthusian thinks. Nevertheless, it remains an influence tending to relieve the stress of overpopulation and might possibly be given a eugenic trend.

Mention may also be made of another line of attack. The advance of psychology has made it possible to distinguish and in some degree to measure the mental incapacities which result in poverty and crime. The development of institutions for the pauper and the criminal has already shown that it is quite possible to deal with various classes of incompetents both humanely and economically. In well-managed institutions they are far happier and more productive than if allowed their freedom. A considerable expansion, therefore, of institutional care for these classes would be advantageous from the standpoints of both humanity and natural selection.

A further factor in relieving the effects of overpopulation is progress in the production of food. While it is quite probable that such progress must continue to take place under conditions of decreasing returns and lowering wage trends, yet the possibilities in sight are considerable and there is some chance that science will discover novel and more efficient methods. It has been estimated that on the basis of present knowledge food production in the United States may be increased 50 per cent. or more by bringing new lands under cultivation; and as we have already seen, comparisons with other countries indicate that the yield per acre may be nearly doubled. In the overcrowded countries of Europe and Asia some increase of lesser degree will doubtless be attained. In the tropics of South America and Africa the supervision of the white race may yield a considerable increase. Something may also be said for the potential productivity of the "Friendly Arctic" and for a possible increase in the supply of sea foods. Progress in these various directions will at least serve to put off the evil day that the Malthusian predicts, though not without the disadvantages of diminishing returns.

Nevertheless, after all due allowance is made for exaggerations and omissions, it remains true that the Malthusian is calling upon us to face the fundamental facts of a new age. There is no escaping the conclusion that the era of rapid and easy expansion is drawing to a close. And it must also be evident to the student of history that the world will be profoundly affected by the change. The conditions that have fostered the age of democracy in both its economic and political aspects are disappearing, and the conditions which in past ages have made for mass-poverty, conflict and aristocracy are returning. While this does not prove that the world will revert to its evil past, it does emphasize the necessity of an informed and enlightened statesmanship. Only an application of scientific methods to social management gives promise of escape.

We may observe, however, that for reasons already stated it is Europe rather than America which must bear the brunt of the renewed population pressure. Because of our development under totally different conditions we are wholly unprepared to understand the situation of the European peoples, either by way of sympathizing with them in their difficulties, or of appreciating the dangers arising from their militaristic tendencies. With us the acquisition of foreign markets is a relatively unimportant incident affecting normally not much more than 10 per cent. of our trade. It would be quite possible, in fact, for us to reduce this trade to a bare minimum and still to be prosperous. Hence we look upon the aggressive commercialism of Europe, and the imperialism that goes with it, as

simply evidences of degenerate greed, never stopping to think that the clamor for markets is merely the obverse side of the insistent demand for food on the part of an ever-growing population. It is, of course, with the proceeds of the sale of their manufactures that the industrial nations of Europe buy their food imports. If markets fail, unemployment and starvation become inevitable. What, therefore, must be the attitude of the governing classes of Europe as they view the rising tide of world competition in manufacturing and in the appropriation of the food surplus. Unless they can succeed in finding raw materials for their manufactures and markets for their products they are in real danger of popular disorders and even of anarchistic uprisings. Yet we persist in viewing their aggressive policies as being inspired merely by a deliberate malice. It is assumed that if kings and diplomats could be prevented from misleading a peace-loving and industrious people, all would be well. That the simple peasant, rearing his large family in the overcrowded regions of Europe, may possibly be more instrumental in producing conflict than diplomats and militarists together seems incredible to us. Yet in fact the turmoil of Europe arises chiefly from the difficulty of feeding the increasing populations and of meeting their insistent demands for higher standards of living. And this turmoil is likely to continue until an adjustment to the new world situation is reached.

In our own more favored land, however, the change to the new conditions is coming very gradually, and no serious consequences need be anticipated for many years to come. It is true, as we have seen, that the rapid rise in wages which characterized the period of an expanding frontier came to a close about 1900 when diminishing returns in agriculture were first in evidence. But, relatively speaking, our population is still a sparse one, being little more than a tenth as crowded as are the industrial peoples of Europe. Besides, with its higher standards of living, it is already adjusting itself to the new conditions, as is evidenced by the decline in the average size of the family from 5.6 in 1850 to 4.3 in 1920, and by a parallel fall in the decennial rate of natural increase from 25 to 11 per cent. Our new policy of immigration restriction is also materially helping to postpone the day of surplus population, and has already helped to give wages a renewed upward trend. Hence, though land values may be expected to continue their rise after the period of postwar readjustment is past, no rapid cheapening of labor is to be expected. The conditions, therefore, which are becoming so apparent in Europe, by which property and privilege are elevated, while the value of human life is depressed, will come upon us slowly if at all.

BOTANIZING IN ECUADOR

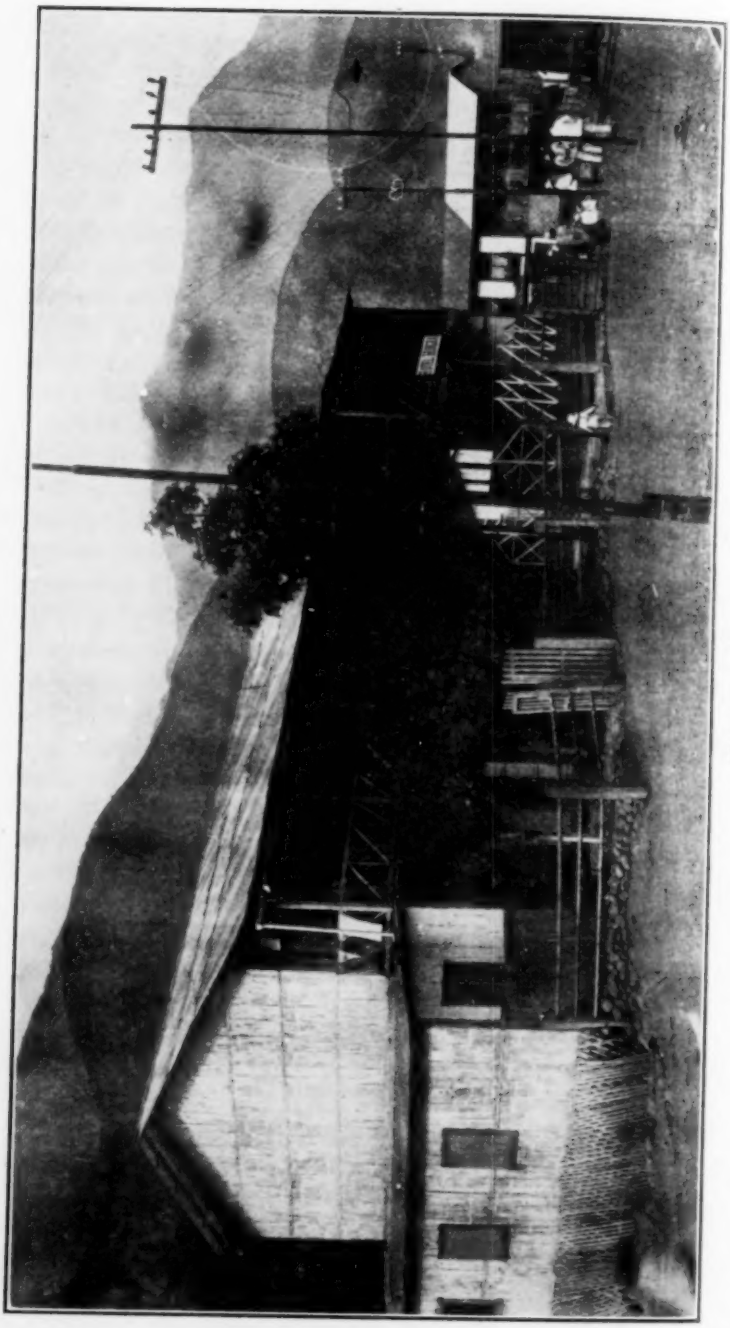
By Dr. A. S. HITCHCOCK

U. S. DEPARTMENT OF AGRICULTURE

In my study of the grasses I have found it necessary to do a large amount of field work in order that I may really know the plants and their habits. In recent years my attention has been turned to South America, partly because of my trip to British Guiana in 1919 and partly because of the great influx of plants from that continent most of the grasses of which were submitted to me for identification. The Gray Herbarium, the New York Botanical Garden and the U. S. National Herbarium have adopted a policy of cooperation in the study of the plants of northern South America. In accord with this policy, I made arrangements to visit Ecuador for the purpose of making a general collection of plants in three sets for the three institutions mentioned. In order to take advantage of this situation, I was authorized to visit Peru and Bolivia, where I devoted my attention in the main to a study of the grasses. The three countries included the region of the central Andes, and the results of the study of the grasses here added to that given to the grasses of Colombia and Venezuela collected by Dr. Pennell and his assistants in the former, and by Pittier, Jahn and others, in the latter country, would give a fair idea of the grass flora of the Andes within the tropics.

So it came about that my wife and I started from New York on May 25, 1923, on a Panama railroad steamer for Cristóbal. We landed for a few hours at Port au Prince on the way, and arrived in the Canal Zone on June 2, where we waited until June 10 for a boat to Guayaquil, the *Huallaga* of the Peruvian line. A few grasses were collected at Buenaventura, where a stop of a few hours was made, and then we proceeded to Guayaquil, landing on June 16.

Landing from a steamer in a strange country is always a nerve-racking process—there is the health officer, the passport examination, the custom house, the landing of the baggage, the unfamiliar money and, since landing was by lighter and launch, the bargaining for passage ashore with greedy cargadores, a dozen of them all pushing and talking and gesticulating at once. I was greatly relieved when a man came forward with a letter from Mr. James Rorer, the well-known mycologist, whom I had met in Trinidad. The bearer would look after my things from steamer to hotel, including custom house. Oh joy! what relief! And he did it, too,



HOTEL AT HUIGRA

The side walls are sheathed with bamboo boards, a common building material in western Ecuador. The stems are split down one side and flattened out.

and the price was reasonable. Fortunately I had a letter from the Ecuadorean minister in Washington to the custom officials in Guayaquil which smoothed things wonderfully. We had nine pieces of heavy baggage, including two large boxes of collecting paper with the tops screwed on. The custom house was hot and steamy. "These boxes contain paper for my plants, shall I open them?" "Oh no, Señor, that is all right." The pieces are checked and off we go. Mr. Rorer himself could not be there, as he was on his plantation in the interior.

For a few days I was busy getting in touch with officials and others who might be able to help me, making connections, as it is called. Dr. F. W. Goding, our very kindly and efficient consul-

A Fine Summer Residence at Huigra

The walls are of two crossed layers of bamboo board covered with stucco.

general, was of inestimable service. The governor of the province gave me a letter, in Spanish, to officials, a letter of especial value in remote regions where a plant-digging idiot would be under grave suspicion.

While wandering along the river front in the city, I saw a grass growing in the tidal mud which proved to be a little known species described by Kunth from the collections of Humboldt and Bonpland at the time these naturalists visited Guayaquil at the beginning of the last century. The name, *Eriochloa polystachya*, had been applied to other species in the United States and tropical

A HOUSE UNDER CONSTRUCTION, CUENCA

The poles are tied to the frame with agave fiber. The cultivated fields are carried far up on the mountain side. An agave hedge back of the house. Four eucalyptus trees in background.

Teresita, a very wet belt close to the mountains; at the plantation of Mr. Rorer, who is raising cacao, coffee and bananas; at the sugar plantation in charge of Sr. Perez Conto, near Milagro. At the last place, Mr. Meigs, the manager, and Mr. Platts, the chemist, are Americans, the latter a class-

FRAME WORK OF HOUSE

The small cross pieces are carrizo (Arundo donax).

America, none of which quite agreed with the original description and plate. Here was the real thing—and from the type locality—another puzzle solved!

While at Guayaquil, I had the privilege of collecting at several places on the coastal plain: Through the courtesy of Mr. Orr, geologist, and Mr. Clark, superintendent, at an oil camp toward Salinas; at the plantation of Mr. Cleveland at

FRAMEWORK OF HOUSE

It is partly filled in with mud. Later the walls will be plastered.

mate of my daughter at the University of Michigan (so narrow is the world!).

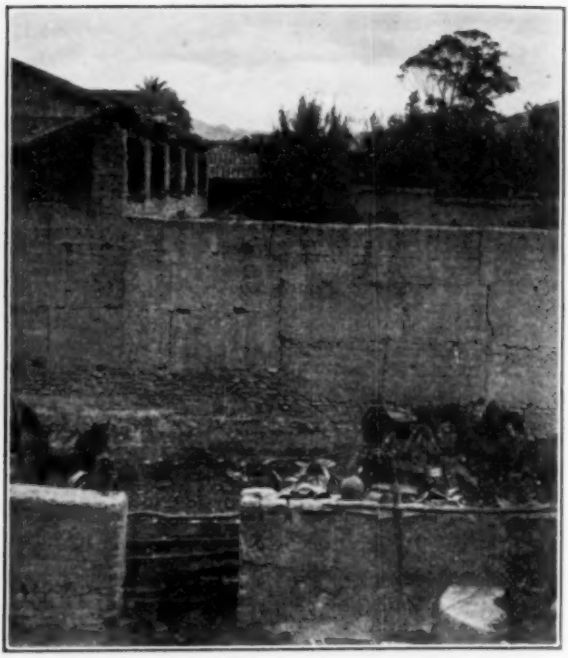
Guayaquil is warm, but not so warm as Panama. The whole coast of South America south of Colombia is kept comparatively cool by the Humboldt current coming up the coast from the Antarctic regions. The temperature at Guayaquil rarely goes above 85° F. Formerly this city was a hotbed of yellow fever and other tropical diseases, but is now clean and safe.

AN ADOBE HUT

With plastered walls and grass-thatched roof. Common type in the Sierra. The trees are eucalyptus.

For a part of the time we had our headquarters at Huigra, in the mountains on the railroad to Quito. Here at an altitude of 4,000 feet the climate is very fine. The Guayaquil and Quito railroad crosses the coastal plain and then rises laboriously up through a steep valley to the Sierra, getting up to 10,000 feet in a few miles, and then goes down into a high valley and passengers stay over night at Riobamba. The road was a difficult piece of engineering. Up through this valley the grade is often 3 to 5 per cent. and reaches a maximum of 5.5 per cent. The mighty engine did much chugging to get its little train of four cars up these grades. The

HOTEL AT MALCHINGUI



CORRAL AND TOILET ROOM OF HOTEL AT LOJA

Note the open well in right foreground. All water should be boiled before drinking.

second day is spent going from Riobamba to Quito, over successive passes and valleys past mighty Chimborazo to Ambato and Latacunga, past superb and graceful Cotopaxi into the bowl near Pichincha, where is located the capital at 9,500 feet altitude, a rather cold place because of its height.

Arrangements were now made for a trip to Tulcán on the Colombian border. I was very fortunate in obtaining for a companion Mr. J. R. McWilliam, a young American living in Quito, a Seventh-Day Adventist missionary. He speaks Spanish and is familiar with the country and its customs. Still more important, he is a gentleman of high character and proved a helpful friend as well as an efficient aid. Mr. McWilliam accompanied me on my other trips in Ecuador. He attended to the business details of the expedition and served as a buffer between me and extortionate guides and mule-owners. Those who travel in out-of-the-way places will agree with me that much of one's energy is used in getting from place to place and the unescapable details are such a severe tax on one's time and patience that little of either is left for scientific work.

The limiting factor in travel by mule is forage for the animals. The animals are given no grain, but are fed night and morning, and also noon when possible, some kind of cut green forage, alfalfa when available, otherwise, corn stalks, sugar cane, barley, bamboo, gamalote (*Axonopus scoparius*), or even wild grass or weeds. Necessity for obtaining forage compels stops for the night in the cultivated valleys, and therefore at the inns of the towns or huts of the Indians. The botanical specimens of interest are obtained mostly on the ridges and passes between the valleys. If night threatened to overtake us in good collecting ground we were obliged to hurry on to the next place where our animals could be fed.

The first night out of Quito we stopped at a ranch which was accustomed to supply shelter and forage to traveling caravans. I had a saddle that I had brought from home, and I carried a folding cot with a pad or thin mattress and blankets. We were assigned to a room without furniture, water, light or conveniences of any sort. We were able to obtain hot water, the rest of the meal we supplied ourselves. One must travel with bed, supplementary food, candles and simple utensils. Fleas, lice and bedbugs are likely to be encountered and care must be taken to remain free from attack.

The day's travel out of Tulcán will illustrate the troubles of a plant collector. We arose at 2:50 in order to have an early start and get out of the valley to good collecting soon after daylight.

A Wayside Inn

Our caravan ready to start. Mr. McWilliam on mule in center.

A Bale of Unfinished Panama Hats
They are being wrapped for shipment at Cuenca.

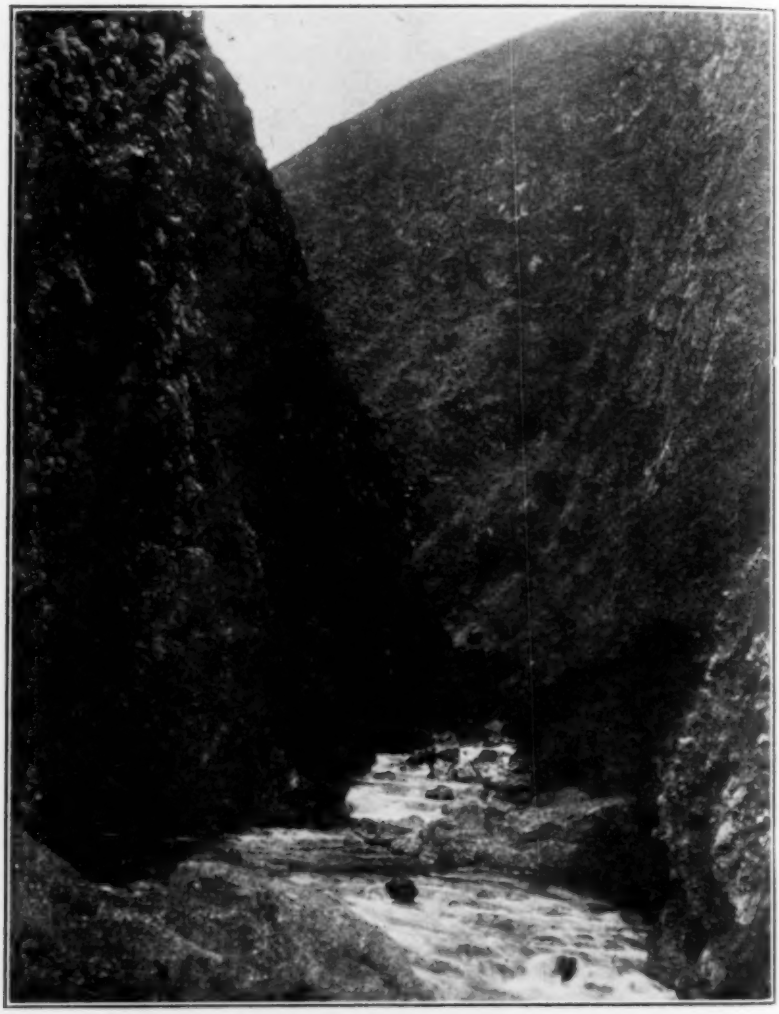
I was suffering from a rather light case of diarrhea and was confining my diet to boiled milk. I drank a bowl of milk for breakfast and filled my canteen with milk. We were able to start about five o'clock and then proceeded through the uninteresting valley for an hour. Our destination was La Rinconada, a large ranch on the way to Ibarra where we had stopped on the way north. Collections were made, partly in the rain for about two hours and then we hurried on for the páramo that we had passed through on the way over. A páramo is a ridge, slope, or plateau above tree line and has a characteristic flora. It is a bleak place often with a cold wind sweeping over it, often with squalls of rain or even sleet. In the afternoon we arrived on this páramo and hurriedly collected as long as we dared spare the time and yet get to the ranch. Here we saw a wonderful forest of frailejones, a treelike composite that forms extensive forests for miles over some of the hills of the páramo. The trunks are mostly 6 to 8 feet high but may be as much as 15 feet. The collecting here was so good that we remained longer than we ought. The road we were following was not the main highway between Tulcán and Ibarra but a fainter road to the La Rinconada Ranch. Darkness soon overtook us, and we had to trust to the mules to follow the path. As they were not familiar with the region there was danger of their following the wrong road and this is what they did on the ranch itself. About ten o'clock,

in darkness so dense that we could not see the heads of our own mules, we found ourselves ascending a very steep hill, so steep that our pack animal stumbled and fell. The animal was down on the slope with the pack slipped under its belly. Here was a disaster of major importance. Removing a pack from a frightened mule in the dark is ticklish business. Passing over troublesome details we finally reached the ranch house amid the barking of about a thousand dogs. Even with this bedlam, the servants were unable to awake the owner and we put up our beds in the kitchen. I had had nothing to eat since 4 A. M. except a quart of boiled milk in my canteen. We were given a bowl of hot milk and finally retired at 1:50 A. M., a day of 23 hours, much of it in the saddle. This is a sample of the vicissitudes of the traveler in remote regions.

The next trip was through southern Ecuador. We went by

TILLANDSIA

A tree with several species of Tillandsia (wild pines or bromeliads), Southwestern Ecuador. Epiphytes are very abundant in this region.

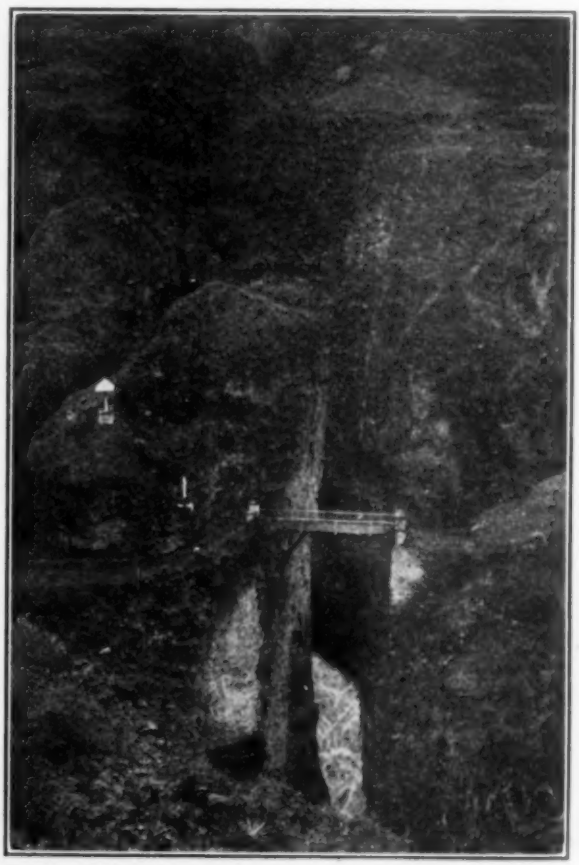


A Mountain Gorge near Oña.

boat to Santa Rosa and with mules by stages to Loja, Cuenca and Huigra. The method of travel was to hire the animals and a driver for each stage, two pack mules for the outfit and three saddle mules for McWilliam, the muleteer and myself. The muleteer was responsible for all the animals, looked after the loading, feeding, saddling and anything else there was to do, and was also guide and interpreter with Indians who could not speak Spanish. Payment was made in advance to the responsible party from whom the mules were hired, the price averaging 5 sucres each per day for the mules and the man. At this time the sucre was worth about twenty cents. At no time during my entire stay in Ecuador were

the mules brought at the hour agreed upon—we were in a mañana country.

The first stage, two days, took us to the gold mine at Portovelo near Zaruma. Here we were the guests of the company by courtesy of Mr. Tweedy, the manager, and Mr. Kellogg, the superintendent. It is worthy of record that we had here good American griddle cakes and syrup. The second stage, three days, brought us to Loja, where we spent one day drying plants. In five days more, including one day's rest on the Sabbath (Saturday, Mr. McWilliam being a Seventh-Day Adventist) at Oña, we reached Cuenca, the third city of Ecuador. This is one of the centers of the Panama-hat industry, almost the entire population weaving the hats. The palm is a native of the coastal region, but the young leaves are brought up to the highlands to be made into hats. The city is much isolated as its nearest railroad connection is at Huigra.



BRIDGE ACROSS GORGE AT BAÑOS.

FRAILEJONES

A forest of frailejones (Culcitium sp.) páramo of Northern Ecuador.

Much of the traffic of Loja is out by way of Paita in northern Peru. Two days' travel from Cuenca brought us to Huigra.

The collecting was good on the trip but as usual the interesting plants were found on the wet ridges between the valleys or on the páramos. Twice we spent the night in the mountains in order to get sufficient time for collecting. The forage question is troublesome, as it is not easy to provide feed for the animals. If wild grass is available the animals must graze during the night when they ought to be resting. In wooded regions there is no suitable grazing.

AN AGAVE-LIKE PLANT IN A FOREST OF FRAILEJONES

The kindliness of the natives is illustrated by our experience on one of these occasions. We came to a small hut at about 11,000 feet and asked if we might remain for the night. "Como no, Señor?" (Why not? or surely.) The hut was of brush thatched with grass, ten feet by six, a doorway but no door, no windows, a dirt floor. In one end there was a raised platform, which was the bed. The only equipment consisted of three blankets and quilts, about half a dozen tin dishes and three stones on the floor for a fireplace (no chimney). Here lived a man, his wife and four small children, the youngest a baby of six months. Being the

A Frailejone Plant about Eight Feet Tall.

guests we occupied the platform. We had all our clothes on and our blankets, ponchos, sweaters—everything available. The cold páramo wind came through the brush side of the hut with scarcely decreased violence so that we had to wrap our heads. Yet these people were living here—and ready to give us the best they had.

I was astonished at the great number and variety of the tillandsias or wild pines, most of them epiphytic on the trees, sometimes five or six species on a single tree, but some of them growing on the ground or on rocks. Epiphytic orchids were more common here than in the other parts of Ecuador I had visited though the region was rather arid.

It is well known that in tropical regions, especially at lower altitudes, the individual trees of a given species are much scattered in the forest. I had an opportunity on the west slope of the Andes to observe this and estimate the degree of isolation. One species was in full flower with conspicuous red inflorescences. At one point on a hill I was able to look over many square miles of forest, and could easily detect the individuals of this species. I estimated that the trees would average one to the square mile.

The last trip with Mr. McWilliam was from Ambato to Baños and on into the Oriente to Cashurco near Mera, occupying four days. We passed the great volcano Tunguragua (16,700 feet) which was belching vast columns of smoke. The trail down the gorge of the Pastaza River takes one through scenery that is indescribably grand. From Baños to Cashurco the collecting was unusually good. In a single day I obtained 150 species of plants that I had not found before in Ecuador.

Before leaving Ecuador I ascended Chimborazo to the snow line at about 16,000 feet, starting from Urbina on the railroad at about 12,000 feet. The trip was made on foot in one day with a native guide.

MENTAL HYGIENE IN THE UNIVERSITY

By Dr. STEWART PATON

PRINCETON, N. J.

MENTAL hygiene is one of those useful but indefinable terms which is still on probation in academic circles. The term is not on the Index, but it has not been formally recognized and accepted. As the term became prominent it encountered some if not all the opposition that once was forcibly expressed against recognizing such words as health, disease, sanity or insanity as fit subjects for academic discussion.

It is not so long ago that the intellectuals did not consider health, sanity, culture and civilization as words belonging in the same category. An intellectual was expected to radiate both culture and a civilizing influence, but he did not stop nor stoop to consider questions of hygiene, either physical or mental. The times fortunately have changed. Mental hygiene redirects attention to the Greek point of view that stresses the value and relations of a sound mind to a sound body and of bodily vigor to mental alertness. As a matter of fact there is some danger now of misdirected enthusiasm and skill in advertising, giving mental hygiene the kind of prominence it neither desires nor deserves.

I hope, however, to be able to point out in what follows the kind of attention and encouragement mental hygiene deserves and expects to receive in the university. Before doing this let me say that mental hygiene represents a happy combination of the methods of art and science intended to secure a little bit more intelligent regulation of our lives. Mental hygiene, however, is not proposed as a panacea for all our ills. It does not insist that there is only one road to salvation, nor does it offer a specific remedy guaranteed to cure every form of mental and spiritual disillusionment.

Perhaps it is just as well for us to remember that one of the chief functions of mental hygiene is to point out the obvious. Those telling about the advantages of mental hygiene must expect to have the same experiences, which Professor Santayana has said generally come to those who are engaged in championing the obvious. On the one hand, some people will say it is both futile and silly to dwell on the obvious, while on the other side, there will be docile minds ready to bow before "Plain words as before some sacred mystery."

Although mental hygiene is only one half art and one half

science and does not have any promises rich in dramatic possibilities to offer, it is a very important subject. It serves to remind the academic psychologist that education should prepare a student to live in the world of reality, as well as to enjoy the protected environment of the university. A little knowledge of its principles should make it easier for members of a faculty to live together in unity, for teachers to teach, for students to learn, and for all to develop a little more intelligent interest in acquiring the art of living within their emotional and intellectual means. Mental hygiene tries to make it easier for all to catch the rhythm in the dance of life.

It is not difficult to find plenty of illustrations of the advantages the members of a faculty could secure from even a slight acquaintance with the ordinary rules of the art we are describing. I happened once to be walking with a friend who is a philosopher by profession, and we chanced to meet another professional philosopher, an acquaintance of both my friend and myself. I noticed the second philosopher responded to my greetings but took no notice of my friend. After we had passed, I said to my friend, "B. does not speak to you. What is the trouble?" "He never liked my criticism of his work," replied my friend, "so he does not notice me." "Evidently B. is an academic but not a practical philosopher," I said, "and of course it is safe to assume he is not interested in any subject as practical as mental hygiene."

Mental hygiene can be counted upon to furnish material assistance to members of committees on discipline and the curriculum in developing human and humane views on the subject of education. Emphasis is placed upon the original meaning of the word education—a drawing-out and not a putting-in process. An appreciation of this fact should bring to the attention of the teacher the importance of finding out something about the nature of the processes he expects to draw out of the pupil. What a marvelous change would take place in the whole educational system if the teacher once grasped the idea he was not engaged to superintend the storage of academic cargoes, but to direct the delicate adjustment of very complicated brain-processes.

The reaction of a good many teachers towards the statement of the fact that students have brains is similar to that of an English clergyman I met years ago in Naples, and who asked me what kind of work I was engaged upon at the Naples Aquarium. When I told him I was studying the brains of fish he sat silent for some time puffing on his pipe, but finally asked, "Did I understand you to say that fish have brains?" After assuring him that fish did actually possess brains he suddenly showed signs of considerable enthusiasm for a new discovery by ejaculating, "By Jove, that's quite an idea!"

My experience in academic communities has convinced me that if the average professor does realize that students have brains, then these authorities on education do not seem to be very enthusiastic about the significance of this information. If they did understand what it was to be the happy possessor of a brain they would appreciate what a wonderful organ the human brain is not to be thrown out of kilter more often by the varied and complex disadvantages of a thoroughly modern education. A special license is required in order to experiment upon the brains of the lower animals, but no license is required to-day from the multitude of teachers in schools and universities who are experimenting on the functions of the brains of students.

Perhaps many will consider me unnecessarily severe in criticizing institutions of learning. Let us see if this attack is justified. Recently I had a long and interesting conference with one of the chief academic representatives of one of the oldest, largest and best known of the eastern universities. "Suppose," I said to this official, "I happen to be a professor of history in the institution you represent, and Jones, an undergraduate member of my class, is not doing well in his studies. I take a personal interest in Jones, and wish to find out what the reason is for Jones's poor scholastic standing. Undoubtedly there is considerable information in the university bearing on Jones's case that may throw some light on the reason for his continued failures. In the first place, there may be items of interest contained in the results of his physical examinations, of intelligence tests, of university examinations, of reports from the schools which he attended before entering the university." We counted up, I think, seven different possible sources of information about Jones. "But," said my friend, "if you wish to get all this information you would have to go to at least seven different offices on the campus." My reply to this was that as I was presumably a very busy professor, I should not have time to get the information, and when Jones failed in his examination he would be dropped from the class and neither he nor I would know just why he was dropped. Think of educators not making an effort to study their failures intelligently! What a comment this is on our entire educational system—the one system in which we would think a careful study would be made of each failure in order to improve the methods! How the professor in the class-room loves to tell his students to profit by their failures, and yet how very little he does himself to set the student a good example in this respect. The relatively large amount of information now available in the universities would, if properly coordinated, supply the faculty with useful data about the real reasons for students' academic successes or fail-

ures. This same information if properly used would throw light upon the ease or difficulty students frequently experience either in recognizing or adjusting their personal problems.

Here is a very striking illustration of the harm often done by trying to stimulate intellectual interests in students at a time when nature is trying to protect the pupil from the meddlesome interference of teachers. The protective reaction is usually one in which lack of interest in study is a prominent symptom. Often, as has been shown by Dr. C. G. Guthrie at Lawrenceville, as the result of rapid growth associated with undernourishment, boys in the school period begin to show signs of not having sufficient reserve energy for both work and play. They seem to be and are always a little behind the game. Soon these boys develop a series of protective reactions. These responses, usually exaggerated by repeated attempts made to develop at an inopportune time intellectual interests, include signs of emotional instability, irritability, lack of interest, inability to fix and concentrate attention and a variety of other symptoms which may become permanent unless the underlying causes are removed. As a rule, the cases of these boys are not recognized and they go from school to college and out into the world sadly handicapped by mental attitudes and habits that are indicative of nature's efforts to compensate for a fundamental sense of inadequacy that can be traced directly to physical causes. If the physical causes of the mental disturbances had been removed, then the pupils would have adjusted their lives and developed healthy intellectual interests.

A slight knowledge of mental hygiene would often make it easier for the teaching staff to understand that pronounced cases of mental disorder, now occurring all too frequently among the students, exhibit mental peculiarities that are not in any way specifically different from those met with in the average person. The little personal prejudices, obsessions, fixed ideas and various complexes from which we all suffer differ merely in degree but not in kind from those occurring in psychotic conditions. If then, it is to be a function of the teacher to assist students to develop mental poise, to keep their minds as free as possible from prejudices and obsessions, and to give assistance in cultivating the special emotional attitudes towards life favorable for the growth of genuine culture, attention should be given to the pronounced disorders in order that the educator may be familiar with the forces shaping the organization of every personality.

I shall not say very much about the incidence of mental disorders among the undergraduates in our universities. That is a

topic deserving special treatment. Before I leave this subject, however, I wish to say that the occurrence of pronounced mental trouble during the university period and the indications in other cases of serious trouble brewing, if difficulties in adjusting life are increased above a certain point, is very much greater than I had any idea of before undertaking these studies.[1] There is no reason to be alarmed in regard to the present rate of incidence of mental disturbances among the undergraduates, as we have no figures to indicate whether the curve is rising or falling. The presence, however, of such a relatively large number of cases in itself is a very serious problem. It is just one more indication of the fact that man is paying an absurdly high price for what we call modern civilization.

One result of ten years' study of the emotional and mental life of university students has made it very clear that what is needed is adequate provision to make a careful correlation of the physical and mental characteristics of one or two classes of students observed during the four years of undergraduate life. I feel confident that if adequate provision were made for completing a research of this character it would be one of the most valuable contributions that could be made to education.

During the period devoted to this research the members of the staff engaged in the work would be receiving a very valuable training that would enable them later to carry on the work in other universities, colleges and schools. Already there is great need for investigators trained in the methods of psychobiology to organize and direct the work in various institutions. At present I have been unable to recommend candidates with the training and experience essential for studying the problems of human behavior and conduct to three university presidents, and at least a score of prominent directors of schools who have expressed their intention of starting work along the lines I have indicated in the institutions they represent.

The establishment of departments in our universities for dealing with the problems of human behavior and conduct would accomplish the following objects:

(1) Indicate that at last the chief study of mankind has been recognized as the study of man.

(2) Make provision for discovering the signs of mental disorders occurring in students at a time and under conditions when treat-

[1] I wish to take this opportunity of expressing to Dr. Joseph Raycroft, director of the department of physical education and hygiene, and his associates, as well as to Dean Howard McClenahan, of Princeton University, my appreciation of the assistance they have given me in making these studies.

ment would often prevent tragic occurrences and give the patient a much better chance of making a satisfactory readjustment in living.

(3) Assist students to correct many of the personal peculiarities and unfortunate habits that so often stand in the way of their securing more solid satisfactions, genuine pleasures and greater efficiency in living.

(4) Bring home to educators the vital importance for our civilization of getting completely away from the present academic attitude of stressing the importance of measuring merely the quantity of facts students have accumulated, and of paying so little attention to how a student thinks and above all how he meets the exigencies of actual life.

To any one at all familiar with the rather narrow views on education now frequently expressed by the intellectuals, it is apparent how important it is to turn our attention to the biological significance of education.

If the information relating to the individual student's educational problems, which is now on file but relatively seldom used, were applied, some important results might be expected. In the first place, the student would receive from academic authorities more intelligent assistance than he does at present in the adjustment of his personal problems. In the second place, the study of individual cases would assist the instructor to acquire a new and very much broader interest in the development of teaching as a fine art. A practical result of paying as much attention to elevating the standards of teaching as is now done to raising the standards of examination would make it possible for students intending to enter professional schools to do this much earlier in their careers. I believe that if sufficient attention were given to improving the art of teaching and in aiding the student not to accumulate information but to improve the character of his mental processes, at least two years could be saved those entering professional schools.

For the past two decades there has been a constant effort made to raise the intellectual standards in the university that is out of all proportion to the attention paid to raising the standards of teaching. Probably the medical schools have been the worst offenders in this respect. The officials have made the naïve assumption that the introduction of laboratory and clinical methods has been an indication of improvements in the art of teaching. Of course, to a very limited extent this is true, but in the medical schools as well as in other departments of our universities educators are still obsessed with the notion that man can afford to fix his attention

on the goal in view without giving equal consideration to the means whereby the end is reached. The high rate of incidence of insanity, the great increase of functional nervous disorders, the marked tendency of large numbers of people to dodge reality by taking refuge in absurd forms of mysticism, the astonishing exhibitions of fear of self, exhibited in hysterical eagerness to over-emphasize social relations and to use communistic cravings as blinds to conceal a defective sense of individuality and seriously disorganized personalities are all tragic evidences of what we must expect to pay for thinking so little about the means we use to get an education and to become civilized. The formal recognition of mental hygiene by our universities will at least indicate the willingness of educators to listen to the question whether it is not worth while before it is too late to take more intelligent steps to conserve the brain-power of our race. The fact that society is coming more and more to rely on prohibitive restrictions to direct the stream of human energy should be recognized as a danger signal of startling significance.

STABILITY

By Professor T. WINGATE TODD
WESTERN RESERVE UNIVERSITY

INHERENT conservatism and extreme reluctance to change or even to contemplate change in any time-honored belief or institution —this is the charge upon which modern mankind is thrust into the dock. The indictment is made with vigor and forceful originality in James Harvey Robinson's "Mind in the Making." And much of the heart-searching among thoughtful people of to-day, progressive and conservative alike, revolves around this very problem. The question of the author is the question which every one is asking himself in these times of unprecedented complexity, "How are we to rid ourselves of our fond prejudices and open our minds?"

I do not presume to answer this question or even to assume knowledge of the direction in which the answer probably lies. That is for the future. But one phase insists in thrusting itself forcibly upon my attention, namely, how is it that an attribute, once most significant for man's progress, may in time become a positive menace to his welfare and his true development?

There is no doubt that this is precisely what has happened, although in the realm of the mind, with our present knowledge, it would be a thesis difficult to prove. Perhaps in this very conservatism lies the essential difference between man and other living things. It is not without reason that man has put himself upon a pedestal, has come to consider himself a creation apart, as something very special among the various forms of life upon the earth. But when he tries to explain wherein this difference really lies he is inarticulate. One can identify the faces of one's friends but finds it difficult to describe them; likewise one feels sure that there is something different about man but can not define in set terms what this difference is.

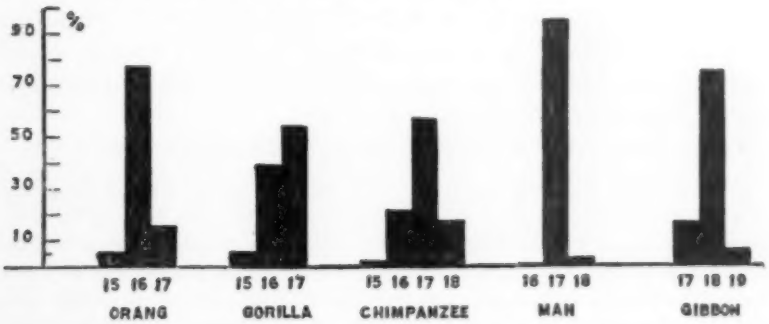
Of course one may say that psychologically man is "different." Our standards of psychological measurement are, however, still obscure and observation along this line difficult and many times uncertain. But nothing is more sure than that body and mind are indivisibly bound together and for this reason I am attempting to define the difference physically.

During recent years it has fallen to my lot to study rather intensively the variability in pattern of man's bodily features and, in order to have some standard of comparison by which this variability may be judged, I have found it instructive to use as a contrast the variability in pattern of the bodily features of other forms of

life which are at least similar in design. It must be understood that in using the body of the anthropoid ape by way of contrast we are, for the moment, assuming nothing regarding origin. We are bound to admit that both man and the anthropoid share life in common, that both are warm-blooded and that they bring forth their young in the same manner. Beyond these facts our argument carries us no further in the present discussion. We can not speak solely in terms of absolute values: we must have some standard of comparison: and there is no better or surer standard of comparison by which we may point the contrast.

The example which I propose to take as a test is drawn from the very core of man's physical being, namely, the character of the vertebral column, a feature which every one would admit is ancient and fundamental. In the chest and loins of a man's body there are, as a rule, seventeen separate bones or vertebrae. But if we

VARIABILITY IN NUMBER OF THORACICO-LUMBAR VERTEBRAE.



enumerate the bones in a large number of human beings, we find some people who have, not seventeen, but sixteen or perhaps eighteen vertebrae in this region. This variability in itself is rather striking, for we have reason to believe that the earliest mammals to make their appearance on the earth had nineteen, whereas certain mammals of to-day have more than nineteen, but others have less. We are not to emphasize, at the moment, the significance of this passing observation. Our immediate problem concerns itself solely with the amount of variation in man.

To render clearer the variability in number of thoracico-lumbar vertebrae found in man, I append a chart showing in black columns the percentage of individuals possessing, respectively, sixteen, seventeen and eighteen. The series upon which these observations were made totals about 850 skeletons; there is no doubt therefore of its essential accuracy. The percentage of individuals possessing eighteen vertebrae in chest and loins is very small and the percentage with sixteen is negligible. Now for comparison I have included black columns analyzing the similar bones in existing anthro-

poid apes. The difference between all these anthropoid figures and that representing man is sufficiently distinct. The characteristic of man is his stability of pattern contrasted with the instability of pattern in the anthropoids. In other words, this means that man differs from these creatures, not so much in his physical features, striking though even this difference may be, but he differs from other creatures in being able to retain a definite bodily pattern. He has not simply attained an ascendancy among living things, but he has been able to maintain that ascendancy and transmit the ascendancy to his offspring with an assurance far beyond anything seen in other creatures. Here, then, is the secret of man's original success. His constancy of pattern, his hereditary retention of bodily perfection, as the French style it, has given him his paramount position in the world of life.

When we assure ourselves that mankind is a creation apart, has characteristics which clearly differentiate him from everything else that breathes, we unconsciously refer to this hereditary stability, call it dependableness, if you will, which undoubtedly is characteristic of man's mind, as it certainly is a dominant feature of his body. It is the fly-wheel by which, in the past ages, his progress has been rendered orderly and continuous.

Let us refer once more to Robinson's stimulating essay:

> There is some reason to think that the men who first transcended the animal mind were of inferior mental capacity to our own, but even if man, emerging from his animal estate, had had on the average quite as good a brain as those with which we are now familiar, I suspect that the extraordinarily slow and hazardous process of accumulating modern civilization would not have been greatly shortened. Mankind is lethargic, easily pledged to routine, timid, suspicious of innovation. That is his nature. He is only artificially, partially and very recently "progressive."

Exactly. The very characteristic which has made man what he is now menaces his further progress. Lethargy and routine are mordanted in his very bones. And yet in spite of this we are witnesses to-day of an extraordinary versatility and energy of mind as though the mind had suddenly shaken off the lethargy which characterizes the body; of a groping into regions of thought and possibility unexplored. What wonder that society is sick. But there is ground for optimism. The ever-spinning fly-wheel may and probably will result in many a troubled and anxious year. The conservative mind will be pained beyond measure and the progressive barely maintain his patience. But in the end, upon this solid basis of control which is man's special inheritance, there will be built a better understanding, a larger and more tolerant comprehension of those fundamental truths by which alone our bounding civilization shall adjust itself to the immutable facts of life.

WHY I TEACH EVOLUTION

By Professor **WILLIAM PATTEN**

DIRECTOR OF THE FRESHMAN COURSE IN EVOLUTION, DARTMOUTH COLLEGE

IT is often said that the moral and religious effects due to the teaching of evolution are disastrous; and even if this is not the case, that evolution, in itself, is not a suitable diet for college freshmen. As our experience does not confirm either of these assertions, it may be worth while to state why and how we teach evolution at Dartmouth.

For the sake of simplicity, and to assume undivided responsibility for this statement, I shall usually speak in the first person.

In the first place, I teach evolution because, in the practically unanimous opinion of those who in one way or another have devoted their lives to the study of nature-action, evolution, or world-growth, is the only logical and unifying concept of natural phenomena there is.

It is a concept that not only helps us to understand what is going on within us and about us, but one that is constantly leading to new revelations in every field of human thought and practice. It is the one basic idea implied, or specifically expressed, in every phase of college and university teaching.

It is essential, therefore, that every young man at the outset of his college career should understand what that idea is, what are the chief facts on which it is based, and what are some of its social, ethical and religious implications.

In the second place, I teach evolution because I am confident, and it is a confidence fully justified by long experience, that the teaching of evolution is the only way to bring back a living God into those fields of human thought and experience from which the teachings of "high-brow" philosophy and "low-brow" religion are excluding Him with extraordinary thoroughness and rapidity.

For there are only three basic concepts of the universe that are possible; either the world stands still in its tracks, as it was made and now is; or else it is going, sooner or later, to destruction; or else it is growing or moving onward in a unified, evolutionary way to what we call higher and better things.

I can not see how there could be any evidence of God in a world that is stationary; and certainly not in a world that is on its way to destruction. If I believed in either of these alternatives, I can not

see how I could have any faith in the existence of a living God, or any worthwhile purpose in life.

On the other hand, the manifold evidence from all branches of science and from everyday human experience that the world is a living, growing world, everywhere and always unified by "natural laws," is to me the surest and the only available evidence that there is a God-like *method* and a God-like *purpose* in it all.

Thus the study of the ever-marvelous phenomena of evolution, done with a full appreciation of their deeper significance, should be the very best way of strengthening religious feelings and unifying social purposes. And that is precisely what it does do, according to the practically unanimous testimony of a surprising number of students who had already begun to call themselves hopeless and aimless "atheists," as well as those who were firm believers in the conventional doctrines of Christianity.

It is evident that without some hopeful, common-sense philosophy of life to vitalize and coordinate our educational system, root and branch, with a convincing and consistent terminology, that system will be fruitless and ultimately self-destructive. For without it, the more we learned the less we would know. Its highest teachings would culminate, as indeed they too often have culminated, in nothing but moral uncertainty and agnostic suicide. It would be a despairing confession that civilization has reached the end of its rope and is doomed to a crashing disaster commensurate with the magnitude of its super-structure and the inherent weakness of its foundations.

The mind refuses to contemplate the horrors of that disaster or the hopeless task of again climbing out of a bottomless pit of ignorance, only to rediscover that life can not logically justify its own existence, and that, after all, it is not worth the effort.

The third and perhaps the principal reason I teach evolution is because the *methods of evolution exemplify the successful usage of the highest ethical and moral principles.* They show us the ideal methods of democracy and of Christianity in successful operation on a universal scale.

Evolution, indeed the very essence of evolution, as we understand it, is a democratic, creative process that has been going on for an infinitely long time; it is still going on all about us, and in it we must play our own parts in cooperation with all its other working members. It is our supreme privilege, as intelligent beings, to understand something of its working principles; but we must understand them to some extent rightly before we may hope to use them successfully in our own creative efforts, of whatever nature they may be.

It may seem presumptuous to say that many scientists, as well as the vast majority of intelligent laymen, do not rightly understand what evolution is or what the working methods of evolution are. The facts, however, clearly point to that conclusion. Scientists themselves are largely responsible for this unfortunate situation. They have been too much absorbed in their own little fields of work; and few of them look beyond those fields, or take the trouble to tell in untechnical language what they have discovered, or what, if anything, they think about evolution *as a whole*. They have left all this summarizing and simplifying for the layman to work out for himself, as best he may. But they are now beginning to recognize their obligations to youth and to "the man in the street," as well as to themselves, and are trying to fulfil them.

A brief panoramic view of the whole subject of evolution, such as we give our freshmen, simplifies, after their first amazement, many of their most perplexing problems, and clarifies our own ideas in a surprising way. For when we inspect with the instruments of science the infinitely large affairs of the heavenly bodies, as well as the infinitely small affairs of atoms and molecules, plants and animals, we readily get the impression that there is a lawful continuity of action in the administrative methods of nature and an insistent trend or drift in the creative results which is clearly indicative of some sort of creative purpose. And eventually, in spite of our prejudices, we are *compelled* to believe that that purpose is the bringing of organic life, of consciousness and intelligence into being on this planet and on many others.

And finally we begin to realize that that purpose is actually accomplished by the cooperation of a multitude of different yet inseparable, "actors"; by many workers or servants, great and small, "living" and "dead," each one, according to its kind, helping and controlling the others in a universal service for that one creative purpose.

And so we see enacted before those "eyes" which science gives us the universal democracy of the idealist in its living and growing reality. It is not surprising that freshmen are so intensely interested in this great creative drama or that they so readily perceive its moral and ethical significance.

We begin the course with a warming up discussion of the more familiar aspects of growth, such as that of a college or some other similar institution. In this pioneering overture, the purpose of the course is explained, its contents outlined and the keynote to the moral treatment of the subject is emphasized.

It is hopefully assumed that with a little insistent pressure the

point of this subsoil plow will eventually penetrate the cold gumbo of the freshman's mind deep enough to break up its hardened crusts of prejudice and prepare a naturally fertile soil for further cultivation.

The next part, called the "Evolution of the Physical World and the Preparations for Life," briefly describes how the scientist makes his discoveries, the instruments he uses for that purpose and what those discoveries mean to him. It tells why the impression is gradually born within him that the physical world is a growing world. It shows that the same elemental agencies, or protons and electrons, atoms and molecules, which play such an important part in the upbuilding of suns and stars are the same agencies which are ultimately used in the upbuilding of living plants and animals; the same ones that provide suitable homes and foods for their continued existence; and the same ones whose chemical activities, whose rhythmic and radiant emanations, such as light, heat, gravity and electricity, direct and control in an orderly way their inner life and their behavior.

From this preliminary study of the physical universe we readily get the impressions that there is an underlying similarity in the make-up and mode of action of the entire universe; and, in spite of what at times may appear to be utter confusion, with apparently no other government than "chance" or accident, that there is after all a resultant order and lawful administration throughout all its affairs.

We find that there is no measurable gain or loss of creative power in this administrative business. *The only recognizable gain is in rightness,* or in those more constructive ways of doing things that we call growth or evolution. We find that the old bugbears of materialism and mechanism finally vanish in those plus and minus symbols of creative energy called protons and electrons, which in the last physical analysis make up the so-called "material" universe. And finally we come to realize that as the silent night, through the instrumentality of the radio, now speaks to us in a multitude of intelligible voices, so through the instrumentalities of science, the "dead" physical universe now speaks to us in intelligible and inspiring terms.

This is not the old, unconvincing mystery of the watch and its maker; it is the clear revelation of a universal creative method. If we may not say that this primeval upbuilding of chemical and celestial bodies was "intended" to serve as the ways and means of a life to come, we may at least say that the whole process of physical evolution has no other intelligible meaning. For it is manifest that

without these particular agencies, or even with any measurable modifications of their peculiar qualities and proportions, protoplasmic life would be impossible on this planet or on any other. And so here, if anywhere, the making and the adequate furnishing of many mansions for eternal life is convincingly revealed.

Under such conditions, life in due season made its appearance on this earth, plants fitting themselves to the life-giving resources of the sunlight, the air, the waters and the soil; animals fitting themselves for a more roving life within the prescribed limitations of their terrestrial habitats.

And then these two great kingdoms of life, each one so different from the other, intermingled in one great democratic social life; each kingdom, like man and wife, being dependent on the other for the fulfilment of its own creative possibilities; and each and every member performing for the others, in its life, or in its death, an amazing variety of essential services.

From this more remote, unprejudiced point of view, the little tragedies of human life gain new significance; for the bodily sacrifices or the expenditures of materials and energy essential to any bodily service are seen to be an essential phase of life itself. Thus the significant fact is foreshadowed that effort, pain and suffering and the successful overcoming of difficulties is essential to that triumphant aspect of beauty we so much admire, and to that feeling of well-being and of well-earned success we call happiness; that even death itself is a spur to life; and that, in spite of death, life really exists and thrives in all its beauty and with all its glorious possibilities.

The second part deals with the more important stages in the further evolution of plant and animal life; and the third with the evolution of human life and culture.

Organic evolution is the subject generally in mind in discussing evolution, and it is the one least understood and most grossly misrepresented by the popularizers of science.

Such writers seem to take a special delight in unbridled exaggeration. They may depict life as something wholly "vitalistic" or wholly materialistic or mechanistic; or as a "bloodthirsty" struggle for existence that is governed by nothing but brute force and pure selfishness; or as a heavenly peace where no one or anything works except man; or they may picture animals, including man, as mere jumping-jacks made of immutable germinal corpuscles pulled by immutable hereditary laws. They like to call themselves special advocates, or opponents, of Darwinism, or Lamarckism, or Weismannism, or Mendelism.

But life is not as simple as these rigid formulas imply. We try to show that all these "isms" and many others play their appropriate parts in various ways and in various degrees.

For plant life and animal life, whether conscious or unconscious, is much like our own. It is a tangled web of success and failure, tragedy and comedy; with the freedom of trial and error and the bondage of enslaving circumstance; with exhausting, killing work and restful, regenerative leisure. It may have the cold placidity of ocean depths or the rushing, sunlit excitement of mountain torrents. It is governed by internal biochemical and "mental" agencies, and by external agencies, cosmic, climatic, geographic and social. It displays the perfection of mechanistic and economic devices and the wildest extravagance; utter selfishness and supreme altruism. All things that live are animated with their own little purposes and all are buffeted about apparently to no purpose. But ultimately the supreme purpose of life and of evolution is accomplished.

A living body is a little, active system existing within and sustained by an infinitely large environmental system. And so the chief problem of animal life is to select, so to speak, a definite plan for the upbuilding and progressive improvement of its own body, a plan that will always be in workable or cooperative harmony with that of its environments. That body, therefore, *should always be sensitive to its environments and adaptively adjustable to them.* In other words, it should have the greatest possible locomotive powers or freedom of action, and it should be self-feeding, self-steering and self-perpetuating.

But to attain that end, the body must be *architecturally oriented* in all its structural details, as well as in its main plan, to the great, directive and controlling agencies of its outer world, such as light, air, gravity and food supplies, so that it can rightly respond to their informing influences. Otherwise it would not be able to discover, to capture and to assimilate its necessary food supplies or to avoid disaster. And finally it must always keep its combustion fires burning and *make some profit* out of the business of living. Otherwise the evolutionary progress of life would be impossible.

There are many different ways of upbuilding multicellular organisms, each one producing a characteristic "type" of bodily architecture, such as spherical, branching, disc-like, radial, spiral and ones that are variously distorted or crooked.

But such "structural" plans, even after many millions of years

of experimental trial, have produced but little in the way of progress and evidently can maintain life only on its lower levels.

There is only one plan that has met all the requirements of continuous life and progress. That is the triaxial-gradient plan or symmetrical growth in three right-angled planes. It produces bodies of six different sides (right and left, head and tail, neural and haemal), in which no two points will ever be exactly alike, however small the body may be in the beginning, or however large and complex it may ultimately become.

This basic plan, which is capable of the greatest variety of adjustments adapted to special conditions, has persisted through many geologic eras. The more important internal adjustments that have been made to meet the new requirements of bodily growth gave rise to that long series of animal classes, such as certain worms, arthropods, fishes, amphibia, reptiles and mammals, which were the more immediate products of those adjustments, and which show us, class by class, the great upward steps in the development of that plan and in the development of man's bodily structure and mental powers.

When we survey this long genetic series, the most impressive fact to the student of comparative anatomy and physiology is the essential identity of the great systems of bodily organs and their component parts throughout the entire series.

The main improvements that have been made from time to time, such as for example a one, two, three or four chambered heart, are what chiefly distinguish one class of animals from another. They may appear in themselves as trivial anatomical details, but they are just the kind of adjustments any good engineer would have made to meet the new demands of the time, without seriously interrupting the continuity of vital service. Hence if the basic plan was essentially right in the beginning, and the working materials fit for the purpose, these readjustments may be made indefinitely, with the assurance of getting better results *in accordance with the rightness of each readjustment.*

And that apparently is the way organic evolution is accomplished. For there is always a "new demand" to meet the new conditions produced by preceding achievements. And it is just because those demands are fulfilled or because certain adjustments are made which do have great functional and creative value that a new and higher class of animals quickly comes into being, with still other demands and with still other creative possibilities.

But organic evolution is not all mechanistic, in this narrower sense. It does not solely consist in the upbuilding of organized ani-

mal bodies. Each animal is itself a working unit in a worldwide social organization. In this more fluid social life fixed architectural patterns are less in evidence, although the economic principles of mutually sustaining services are there as immutable and as much in evidence as in the anatomical architecture of the individual organism.

Moreover, hand in hand with the upbuilding of organized animal bodies and of organized social bodies, those qualities gradually emerge from the alchemy of life which, for lack of a better name, we may call spiritual qualities. They successively emerge, but from no particular part and without any definite cleavage planes, as various degrees of purposeful reactions, bodily and social, such as instincts, intelligence and consciousness. We can not anatomize these qualities in materialistic terms. Yet we can not divorce them from material things, for they are apparently the riper products of architectural organization and in turn are knowable only so far as they have a measurable or fruitful influence on the structure of such things.

These more complex animal instincts and social reactions are marvelously effective in the grand strategy of evolution, even though in the special emergencies of individual life they may be as tragically ineffective as the fluttering of a bewildered moth in the alluring light of a candle or the puttering of a negatively heliotropic senator in the light of international peace. Nevertheless, these less adjustable instincts have insured the perpetuation of life and progress, and they have prepared the way for the birth of intelligence that may be used to advantage in just such emergencies. But human intelligence, if it happily exists in an appreciable degree, is only a supplementary addition to instincts, not a substitute for them.

In fact, intelligence, in spite of its frequent abnormalities and "metaphysical" absurdities, is merely a more adjustable reaction to environments than hearing or seeing or instincts. It is a new, synthetic awareness that adds a new logical control to the steering gear of animal behavior. It is the crowning but still acid fruit of life, which serves to put life into wider communication with its environmental Creator.

Imagine, if you can, human beings that are merely intelligent, and just because of their intelligence, let us say as shopgirls, priests or professors, voluntarily surrendering their possessions to their betters, or joyously sacrificing their lives for the sake of prospective babies and posterity. You may easily imagine many familiar voices exclaiming "Well, I should say not! No surrender to babies and posterity in mine, just yet, if you please."

And yet that is precisely what life has done for untold millions of years without intelligence and still does in spite of intelligence. But it is done only under the *secret compulsion* of all those "mechanistic" reactions, appetites and passions, of all those animal instincts and selfish ambitions, the fulfilment of whose imperative "demands" makes the self-sacrifice of altruistic services the chief aim and the chief pleasure in life.

These grosser animal mechanisms, therefore, have their strategic purpose, and it was essential to perfect them and to establish their supremacy before the more "fickle will" of man could be safely allowed to assist in the operation of his own body or before his more spiritual ideals could attain their maturity. A jellyfish probably has no spiritual ideals, but if it had all the wisdom of the prophets and the ideals of a Sir Galahad, it would still have to pursue its ideals in uninspiring waters and fight its battles with gelatinous tentacles.

One of the very great achievements of modern biology was the revelation of the basic mechanism of heredity. This was largely due to the earlier discoveries of the microscopic architecture of the germinal elements, their lawful behavior in the initiation of a new life and their extraordinary stability in a great variety of conditions. At a later period it was discovered that these germinal phenomena could be mathematically correlated with the laws of inheritance, and that certain inherited characters of the adult organism might be logically interpreted as resultant products of certain corpuscular units having a definite quality and number and a definite location in the germ cells.

And now the biologists, with astonishing assurance and success, are beginning to map out on the minute germinal threads called chromosomes the distribution of these "*germinal units*" (which are somewhere near the order of magnitude of the larger molecules) and to correlate them with hereditary "*unit characters*" of the adult organism.

That is, the biologists are now doing much the same sort of thing the physicists and chemists do when they "correlate" atomic structures and action with their resultant products, such as light and other radiant activities.

But these stabilized "germinal corpuscles" and rigid Mendelian laws of the modern science of genetics do not make life a purely germinal mechanism nor do they preclude the existence of still other stabilizing and controlling agencies of a more general character. In fact, they make their existence more clearly imperative.

For no germ could exist, however righteous or perfect it might be in itself, without the right kinds of environmental soils to grow up in and to grow up with.

And so organic genetics, in its narrower meaning, is only a very small phase of a universal system of evolutionary genetics, in which many different classes and orders of *rightly stabilized heritages*, cosmic, terrestrial, organic, germinal, parental and social, play their directive and controlling parts.

Indeed, one of the most instructive lessons of organic evolution is the gradual development of an elaborate system of parental provision, in which *all* bodily agencies, such as muscles, nerves, blood, bones, instincts and intelligence, cooperate to provide better ways and means for the growth of the purely germinal elements.

From era to era and from class to class, up to man, we may see with most impressive clearness the progressive enlargement of the nervous system and many adaptive modifications of mental and bodily powers, as if they were made for the sole purpose of giving greater abilities and greater freedom of action to parents, in order that they might use those powers for the better administration of their germinal affairs. We see the body making larger and larger food provisions for the germ, and enclosing both the germ and its food supplies of eggyolk and albumen in more ingeniously constructed containers. We see the parents using better ways to broadcast their eggs or hiding them in more secret places or making better nests or homes in which to incubate or nurse them. And when the young are liberated from their more rigid, disciplinary confinement, we see the parents foraging for them, protecting, guiding and educating them to the utmost of their ability, mental and bodily.

Thus the parental body, with all its varied powers and resources, is as much a working heritage for the germ as the germ is for the body.

But even that is not the whole story. For hand in hand with the evolution of these bodily and germinal powers goes the evolution of the broader and looser web of social life. And there, without regard to the ties of kinship, high and low, old and young, plants and animals play their respective parts in cooperation with one another and with their physical environments, to form one great ecologic system of mutually profitable exchange.

All these enlargements of life, therefore, are the products of some kind of cooperative exchange which, on the whole, has been mutually profitable. The peculiar give and take of cellular life or the biochemical upbuilding, unbuilding and exchange involved in

every protoplasmic act is called metabolism. It is the very essence of continuous vital action. On a larger scale, the metabolism of creating, destroying and preserving social individualities and the profitable exchange of social products is the essence of social life; and on a still larger scale, *a similar metabolism is the essence of all the changing phenomena of nature-action, including the making and destroying of such things as solar systems.*

Thus the real meaning of the pyramidal upbuilding of an interlocking directorate of mechanistic heritages, cosmic, organic, germinal and instinctive, becomes apparent, for otherwise there could be no stable or righteous foundation for the crowning products of intellectual and spiritual life.

And if we substitute "established law and order" for "mechanism," for that is what that disreputable word really means, the moral and ethical significance of the entire system of evolutionary genetics is obvious. It is also obvious that the outstanding teachings of evolution are the same as the familiar teachings of religion. For the universal reign of law and order, which it has been the special privilege of science to reveal, is nothing more or less than the revelation that nature is a unified cooperative system and that those better results, called evolution, are only achieved through better mutual service by all its constituent parts and by their better submission or adaptation to one another's requirements. That is the essence of the moral and ethical teachings of Christianity as it is the essence of the moral and ethical teachings of evolution.

And the law of "natural selection," which is the essence of the much maligned "Darwinism," is in reality the expression of a discriminating, selective action in nature, in effect identical with the discriminating disciplinary laws of religion.

This disciplinary natural law merely means that whatever is fitting or right or true, whether it is physical or organic or vital or spiritual in its nature, shall prevail and shall yield its appropriate fruits. If it is not fitting or if it is not right or not true, it shall be fruitless and shall not prevail.

In other words, truth has a saving power and a creative compulsion of its own. We call it the compulsion of intelligence. That is *why* man is compelled to seek the truth and to use it for his own salvation and betterment. And the *doing of that* is what we call science. But if we do not use the truth when it is discovered, if the truth when it is discovered does not make us work and direct our work, if it is not reverified in terms of human conduct, science will be sterile; it will neither bear its appropriate fruit nor have the vitality of reality.

Thus this compelling pragmatic law, which Darwin so clearly saw in operation in plant and animal life and which he called "natural selection," is the same law that is so clearly expressed in biblical teachings, as for example:

And even now the axe is laid unto the roots of the trees: therefore every tree which bringeth not forth good fruit is hewn down and cast into the fire. . . . But the root of the righteous shall not be moved.

Lowbrow fundamentalists and highbrow agnostics will please take note of the "even now," and the reality of the "axe."

And so, if we attempt to summarize the creative methods of evolution and to estimate their directive influence on ourselves, physically and mentally, it is not surprising that the descriptive terminology of science inevitably changes into the moral and ethical terminology of idealism or religion.

This means that in the last analysis religion is merely a different name for science; the one being chiefly concerned with the immeasurable Oneness or Godliness of nature-action, the other with its measurable Manyness, or its distinguishable parts. But both, in their own distinctive ways, seek to discover, to interpret, and to utilize the same realities; and when that is rightly done they will be in functional agreement; that is, they will dictate to mankind essentially the same conduct and justify essentially the same faith.

And science has already visualized the same realities as religion. For in the larger aspects of nature-action, the scientist everywhere sees in operation that natural trinity of creators, destroyers and preservers, with the selective law presiding over all, which all great religions have graphically symbolized, in one way or another, as living gods and demons, and which have always served to direct human thought and human behavior. And the whole tendency of science, as that of religion, has been to reduce these several agencies to one operating cause, or one God.

Scientists everywhere see a certain individualistic *variability* or freedom of action in dead things and in living things, which eventually leads to creative innovation and invention. But that freedom of action is always subject to some external limitation and compulsion or to a restraining and guiding *discipline* which limits certain adventures by destruction and *compels* a more lawful and more righteous behavior.

There is always in evidence the *creation* of a new order of things by the cooperation of those more durable instrumentalities called *heritages*. And since they are eventually utilized as aids to some-

thing else, that process has the essential attributes of *sacrifice, benevolence* and *altruism.*

There is always in evidence some selective *destroying, correcting* or *renovating* of what is no longer fitting or adapted to the new order of nature; and always some selective stabilizing or *preserving of the more righteous ways of doing things, which, because they are more righteous, are more fruitful or creative.*

In accordance with our respective temperaments and the scope of our vision, some of us can see and can wisely profit by our seeing some one of nature's metabolic trinity at work much more clearly than either of the other two. Few of us can duly appreciate all three of them, especially when the destroyer operates on our most cherished possessions.

Thus science and religion offer the same incentives to action and have the same purposes to accomplish; and science expresses in her more comprehensive formulas precisely what all the great religions of the past and present have tried to express in their teachings, but without that sure and intimate knowledge of nature-action which science gives us and which is so essential to the truthfulness and sanity of any kind of religion.

I repeat, there is no difference between what is vital in science and what is vital in religion. In fact, underneath, science *is* religion and religion *is* science. The differences which cause so much confusion are in their protective coverings of dogmas, ceremonials and procedures. They are differences between people; between those with more or less scientific qualities of mind and those who have little or no such qualities.

And so, it seems to me that the study of evolution *as a whole* more than anything else will help to minimize the antagonism between religiously minded and scientifically minded people and will help them to work more peacefully and happily together. For young and old, for highbrow and lowbrow, the study of evolution makes life more significant and more beautiful. It justifies their faith and fortifies their ideals. It makes God a more imminent reality. It helps all of us to understand the purpose of life, and how to accomplish it.

That is why I teach evolution.

THE PHYSICAL BASIS OF DISEASE

V. FLUID ACCUMULATIONS

By THE RESEARCH WORKER

STANFORD UNIVERSITY

"As our fifth group of diseases," continued the research worker as the train pulled out of Ogden, "I have selected diseases due to the accumulation of fluid or exudate in important organs or parts of the human body. Such fluid accumulations may give rise to a wide variety of symptoms."

"That reminds me," said the lawyer. "I have a fluid here that produces very agreeable symptoms. Will you join me?"

"As we are about to enter the Utah desert," said the manufacturer, "it will be wise to do so."

"The fluid that accumulates in the body in certain types of disease," continued the research worker, "may vary from a clear, water-like material to thick creamy pus. In certain cases the fluid may be coagulated to a butter-like consistency. The fluid often contains blood. In extreme cases it may consist almost exclusively of blood. The amount of fluid may vary from a few drops to several quarts.

"Probably the simplest example of fluid accumulation in external parts of the body is the watery accumulation in the deeper layers of the skin in dropsy. Several pints of fluid can often be drained off from a dropsical skin by the insertion of a hypodermic needle. This fluid is usually nearly water-white in color, with no admixture of blood.

"Aside from physical discomfort, the main significance of such a fluid accumulation lies in its indication of abnormal conditions in certain vital organs. Dropsy of the skin can be produced in animals in a number of ways. The administration of certain toxic substances, for example, will so injure the blood vessels that they no longer retain the fluid portions of the blood. There is a resulting constant outward leakage of fluid through the capillary walls with the production of dropsy of the skin and other parts.

"Other familiar examples of fluid accumulation in external parts of the body are the accumulation of pus in ordinary boils and pus accumulations in the joints in certain types of acute rheumatism, particularly in gonorrheal rheumatism. Such pus accumu-

lations are readily reproduced in animals by injecting certain disease-producing microorganisms. The pus so formed is often more or less mixed with blood.

"Pus is one of the most interesting biological products. It is strongly antiseptic, able to kill large numbers of disease-producing microorganisms. Its antiseptic power is about equal to that of one per cent. carbolic acid. Pus also contains digestive ferments, with which it is able to dissolve dead tissues.

"A somewhat different type of fluid accumulation in external parts of the body is brought about by mechanical occlusion of the sweat ducts. Such occlusion occasionally produces numerous small bladder-like cysts in the skin, each filled with clear, water-like perspiration. Occlusion of the minute oil ducts occasionally causes deep-seated cysts in the skin containing white, putty-like, greasy masses. If untreated, such oily cysts or wens may reach enormous size. You have all probably known individuals with disfiguring wens on the scalp or neck."

"The janitor in our office building has a wen the size of a fist," said the lawyer. "Refuses to have it removed on religious grounds. A queer customer. Wouldn't allow his wife to be given chloroform during delivery. Said it was contrary to the Scriptures. 'Children must be born in pain.' "

"Religious objection to the use of chloroform in obstetrical work was common fifty years ago. Prominent clergymen preached against it. I believe there is no official objection on the part of the church at the present time."

2

"Numerous examples of fluid accumulation are found in internal organs. One of the simplest examples is abscess formation in the heart walls. If a small amount of pus from a boil is injected into a vein of a rabbit, so that the pus is mixed with the circulating blood, abscesses or boils will often form in the heart walls. If the rabbit is killed three or four days later, portions of the heart muscle will be found distended with pus. Why the infectious agent localizes in the heart muscle, often without involving other parts of the body, is not known.

"Abscesses of the heart muscle are occasionally found in human beings. Heart abscesses may heal spontaneously, the pus being absorbed or carried away by the circulating blood. In severe cases, heart abscesses so weaken the heart walls that rupture takes place, causing instant death.

"A more common fluid accumulation in the circulatory system is fluid accumulation outside of the heart itself, in the sac or bag

in which the heart is suspended. This fluid may vary from a clear, water-like material to thick, creamy pus, often clotted to a butter-like consistency. The effects of such fluid accumulation in the heart sac are largely mechanical and depend upon the volume of the fluid. These effects are readily studied by injecting non-irritating fluids into the heart sac of animals. With large volumes of fluid thus injected, the pressure outside the heart may be raised sufficiently to prevent the expansion of the heart, so that heart action practically ceases, death resulting almost instantaneously. Pus accumulation in the heart sac can be readily reproduced in animals, by injecting certain disease-producing microorganisms. With coagulated fluids in the heart sac there are often to-and-fro rubbing sounds produced between the heart muscle and the surrounding sac, sounds readily heard through a stethoscope.

"The fluid in the heart sac may be completely absorbed and the heart restored to normal. With pus accumulations, however, absorption is often slow and incomplete. The heart occasionally becomes permanently adherent to the surrounding sac, even growing fast to the structures outside the sac. Such adhesions cause serious mechanical interference with heart action. With each contraction of the heart, the heart pulls inward on the adherent parts, lifting the diaphragm, retracting the chest walls, pulling downward on the trachea. An adherent heart must do several times its usual work to maintain a normal circulation."

"A perfectly hopeless condition to treat," said the manufacturer.

"It is a good illustration of the sort of thing a physician is often up against. There is no therapeutic agent that can conceivably remove the scar tissue connecting the heart to the surrounding parts. Nor can these adhesions be influenced by direct mechanical agents such as massage. There are surgical ways, however, in which the handicap to heart action can be materially lessened. The main handicap of an adherent heart is the adhesion to semi-rigid structures such as the ribs and breast bone. Adhesions to elastic parts, such as the lungs and diaphragm, is a less serious mechanical embarrassment. Portions of the ribs and breast bone immediately over the heart can be removed surgically, leaving the heart covered only with elastic skin and underlying muscles. The heart is thus freed from its anchorage to rigid structures. This materially reduces the resistance it must overcome on contraction. This operation has been performed on numerous individuals with beneficial results."

3

"Fluid accumulations also take place in the respiratory system. The simplest example is probably the accumulation of fluid outside the lungs in the chest cavity. The material so accumulated may vary from a clear water-like material to thick creamy pus. It may be mixed with varying amounts of blood. At times this pus may be coagulated or clotted to form a butter-like mass. The volume of the chest fluid may vary from a few drops to several quarts.

"The effects of such fluid accumulations are largely mechanical. With large volumes of fluid, parts of the lungs can no longer expand, so that respiration no longer takes place in these parts. On account of the generous oxygen surplus in the blood, however, this does not become a serious matter till over half of the lungs are thus thrown out of commission. With coagulated pus, to-and-fro rubbing sounds may be produced between the lungs and the chest wall, sounds readily heard with a stethoscope.

"On recovery, the fluid in the chest cavity may be completely absorbed and the lungs restored to normal. With coagulated exudates, however, the lungs often become permanently adherent to the chest wall. Probably the most unfortunate effect of such adhesion is the tendency of the scar tissue uniting the lungs and ribs to contract, pulling in on the ribs and hindering their movements. Marked deformities of the chest may result from this scar tissue."

"Can those adhesions be overcome surgically?" asked the lawyer.

"Operations within the chest cavity are very difficult. The usual treatment of such cases is to try to prevent deformities by systematic exercise. The deformity of the chest can be largely prevented by this means.

"In place of fluid, air occasionally accumulates in the chest cavity. This air may enter as a result of a wound in the chest wall. Or it may come from a ruptured or eroded bronchus. The lungs collapse more or less completely on the side of the chest containing the air. Blood passing through the collapsed portion of the lungs is no longer aerated. The resulting incomplete aeration of the blood does not endanger life. In fact, the artificial production of such partial collapse of the lungs by the injection of air into the chest cavity is occasionally resorted to as a therapeutic measure. Collapse favors the recovery of the lungs from certain local infections such as tuberculosis.

"Probably the most common fluid accumulation in the respiratory system is accumulation of pus in the lung itself. The pulmonary air sacs over large areas of the lungs may be completely

filled with pus. This is the condition known clinically as pneumonia. The pus very often coagulates in the air sacs. On healing, this semi-fluid material is usually completely absorbed or thrown out as expectoration. Occasionally, however, absorption is delayed, the air sacs eventually becoming permanently occluded with solid masses of scar tissue. This portion of the lungs is, therefore, permanently thrown out of commission."

"I thought pneumonia was an infectious disease," said the manufacturer.

"The pus accumulations in the lungs are usually caused by the presence of disease-producing microorganisms. If certain microorganisms are injected into the trachea of animals so that the microorganisms are drawn into the air sacs on inspiration, pneumonia results, practically identical with the pneumonia of human beings. Recovery from pneumonia comes only after these microorganisms have been killed or otherwise rendered harmless."

"Is there anything in this new serum treatment for pneumonia?" asked the manufacturer. "The papers were full of it a few months ago."

"I believe it would be best to postpone discussion of treatment till we have taken up the various biological forces in the human body, tending to prevent or to overcome disease."

4

"Fluid accumulations are also common in the digestive organs and adjacent structures. Abscesses, for example, may form in almost any abdominal organ. They are particularly common in the appendix."

"I don't see the Divine wisdom of putting such a useless organ as the appendix in the human body," said the lawyer.

"The appendix is usually considered as a remnant of an organ that was of importance during the early evolutionary stages of the human race, but is no longer functionally active. Numerous other examples of apparently inactive ancestral remnants are present in the human body."

"Our Boston friend would consider it irreligious to imply that the human body is not perfectly designed to its present needs," said the lawyer.

"One of the most striking fluid accumulations in connection with the digestive organs is accumulation of fluid outside of the intestines within the abdominal cavity. Large volumes of clear fluid may thus form as a result of mechanical interferences with the circulation by a diseased liver. Equally large volumes of clear fluid

or of pus may accumulate as a result of the local action of disease-producing microorganisms. If certain disease-producing microorganisms are injected into the abdominal cavity of animals, the abdominal cavity becomes rapidly distended with pus, surrounding and bathing the intestines and pelvic organs.

"As soon as these microorganisms are killed by the defensive mechanisms of the body or otherwise rendered harmless, the accumulated pus is often completely absorbed, and the abdominal cavity restored to normal. Usually, however, temporary and often permanent adhesions take place. In extreme cases, all the organs of the abdominal cavity may be grown together in a solid mass.

"The formation of adhesions between abdominal organs may have very serious effects. Adhesions, for example, may be so situated as to interfere with the proper movements of the intestines, causing delay in the passage of food material. The adhesions may even completely close an intestine at one or more points, completely preventing food passage. Such intestinal stoppage, of course, will allow the stagnant food material to undergo fermentation and putrefaction. It will eventually cause death if not relieved by surgical means. In the same way, adhesions may compress the excreting ducts from the kidney, preventing the carrying off of liquid wastes from the body. Or they may surround the female reproductive glands, producing sterility.

"Accumulations of fluid or exudate may also take place within the digestive tubes. The most striking example of this is in Asiatic cholera. The microorganisms of this disease so irritate the intestinal lining that several quarts of fluid are often poured out into the intestinal canal. This fluid is usually expelled from the body, giving the characteristic watery discharge of cholera. The loss of fluid from the body is often so great that the body as a whole takes on a semi-mummy-like appearance. The blood becomes concentrated, changing to a viscid fluid of almost tar-like consistency."

"Is it true that whiskey is the only reliable cure for cholera?" asked the lawyer. "In a recent movie, the heroine contracted cholera. The hero dragged himself twenty miles with a broken leg to get her a bottle of whiskey. He thus saved her life."

"I have often wondered," replied the research worker, "why references to medical subjects in movies and in popular fiction are usually so out of accord with medical facts. The average screen physician is a brainless ass. He looks through the wrong end of a microscope and makes impossible cures. The physician of popular fiction is usually equally absurd. As a pure business proposition, a competent medical critic should be employed by every publisher."

6

"Accumulations of fluid also take place in the nervous system. A familiar example is hydrocephalus. The spinal cord, as you know, has a minute central drainage canal connected at the upper end with a series of drainage chambers in the brain. It occasionally happens that this drainage system is occluded, fluid accumulating, dilating the spinal cord or one or more chambers of the brain. This dilatation and distortion of the spinal cord usually gives sensory or motor disturbances. Dilation of the brain almost invariably causes mental deterioration.

"Another type of fluid accumulation in the nervous system is the accumulation of pus in the skull cavity immediately outside the brain. This is the characteristic picture of meningitis. The condition is readily reproduced in animals by injecting certain disease-producing microorganisms. Part of this pus can readily be withdrawn by inserting a large hypodermic needle into the spinal canal. This is often done for diagnostic purposes."

"Is such an operation dangerous?" asked the lawyer.

"Violent objection to this method of diagnosis was made in the earlier days. I believe the physician who first used this method was a professor in one of our big eastern medical schools. He stirred up such a rabid outcry against 'Vivisection of children' that he was requested to resign. This method of diagnosis is now used in all hospitals."

"We are about to cross Great Salt Lake," said the lawyer. "Let's adjourn to the observation car."

WHO PROFITS FROM SCIENTIFIC WORK?

By Dr. F. C. BROWN
BUREAU OF STANDARDS

SOME years ago a prominent American citizen said that he was not so much concerned with the advantages of the Twentieth Century Limited as he was concerned with who rode on the Twentieth Century Limited. He desired that this special service train should carry passengers who were rendering an increased service to the public by virtue of the increased speed and comfort rather than gamblers, bootleggers, criminals and those who merely flit for a living. We have spoken much of the great savings accomplished by the national Bureau of Standards and by standardization generally. We have shown that the scientific work of the Bureau of Standards has resulted in improved brake linings for automobiles, which work has resulted in a saving of $15,000,000 annually in the cost of brake linings. It is easy to understand that the average pedestrian as well as the automobile driver has a greater safety on the road as a result of better brake linings, but who gets the $15,000,000?

The question has particularly arisen with regard to the saving of wastes and losses resulting from the deletion of excess varieties, grades and sizes of commodities found in commerce. Manufacturers have recognized the enormous economic waste of excess varieties and are most cordial in the support of the Department of Commerce in cooperating to eliminate unnecessary lines of commodities. They have agreed to cut 66 miscellaneous sizes of paving bricks to five standard sizes in common demand. Similarly, asphalt for paving purposes has been cut from 102 to 10 varieties. Range boilers have been reduced from over 130 miscellaneous sizes to 13, brass traps from 1,114 to 72, hot water storage tanks from 120 to 14, hollow building tile from over 300 styles and weights to 19, wire fence from 552 to 69 varieties. Building materials, plumbing supplies and hardware are all being reduced to the minimum number of best standards that are known. A billion dollars may be saved to the country annually through this simplification work alone. With regard to the standardization and simplification of plumbing supplies, the president of the national association declared this to be the most important work being done by the national government and he felt prepared to support his declaration. Of course the manufacturers and jobbers in sheet metal will be pleased with the economies and savings effected by discontinuing nearly a thousand varieties and sizes, but how will the user of sheet metal profit?

This standardization of man-made things may be likened to what has taken place in the products of nature. Take corn, for example. Instead of letting every variety of corn grow as it will among weeds and other vegetation man has simplified the product. Not only is corn segregated from other vegetation, but the best standard of corn is selected and it alone is grown in a particular soil until man succeeds in producing a superior standard.

We have shown that as a result of the study of power loss in automobile tires there is to-day an annual saving of approximately $40,000,000 in gasoline consumption. In addition to this there is a large saving arising from the longer life of tires which are produced at less cost. We have spoken of the establishment of the dextrose industry and we have been willing to make the estimate that millions of dollars worth of the new product will be added to the country's resources. The Bureau of Standards has shown the gypsum industry a method of manufacturing a plastic gypsum. This discovery leads to better plastering at less cost than formerly. The mills are already producing this product. The saving in production and labor should run into hundreds of thousands of dollars annually.

Working with the Coast and Geodetic Survey the bureau has developed a new combination of radio and sound recording apparatus which will enable ships to locate their position near shore during foggy and unfavorable weather. This means that the survey ships will be able to work during all kinds of weather, thereby saving upward of a hundred thousand dollars. But this is insignificant compared with the value of the radio direction finder which was initiated by the Bureau of Standards and is being developed in cooperation with other government and commercial bodies. Within a few years there will be no such thing as holding up ships in navigation because of fog. Radio waves will generally replace the beacon light in time of fog as well as darkness. The saving in navigation costs will run into hundreds of millions annually. Likewise the bureau has developed a number of airplane instruments that have been adopted to meet the most exacting conditions. This work can not be evaluated, however, until the future has placed an evaluation on air navigation.

Quite recently the bureau has developed a new safety release device for use on tanks containing compressed gases for shipment. This improvement will produce an estimated saving of $250,000 a year.

Very valuable contributions have been made to our knowledge of the materials used in huge structures. New strain gages have been devised to accomplish these results. The electrical strain gage, made of a pile of carbon discs, for the measurement of minute changes in the length of materials under varying loads, has already

been used in airships in flight, in bridge structures and in structural test members in the two million pound testing machine, and is now to be used further in road and bridge testing and in the study of the behavior of unusual dams and towers when the loads bring on the breaking point. It is difficult to place the value on an instrument which makes possible better and safer design of huge structures and which saves thereby both money and human lives, but it is easy to believe that the added information has a potential value of hundreds of millions.

In connection with building construction the work of the Building Code Committee, the Plumbing Committee and the Hardware Manufacturers Committee should save hundreds of millions annually in the construction of dwellings and offices. For example, the investigation showed the three-inch stack in plumbing to be equally satisfactory to the four-inch stack now in general use. This fact alone will save a million dollars annually in small dwellings. Likewise the investigation showing a petroleum product to be a satisfactory substitute for glycerine in door checks may mean an annual saving of $15,000. And so on we could relate how the investigation of paints, varnishes, soaps, metals, alloys, etc., all produce in one way or another enormous savings in American manufactured goods. Large savings have accrued in the production of government specifications in order that the government may get a uniformly good product for its money. One department this year saved $70,000 on the purchase of varnish as a result of these specifications. Three men working for a year in the telephone section were able to cut the annual telephone bill in Washington by $85,000 without injuring the service. I believe that already the Bureau of Standards has played a key position in adding a billion dollars annually to the wealth of the nation. But suppose one institution does bring about such increased efficiency and these enormous savings in American manufacture, who gets the profit?

The scepticism on the part of some of the public, particularly those who may at some time or other have gone in for profit in oil wells or gold mines, is very well illustrated by the story told by the Iowa farmer who was about to buy cheaper land in Louisiana. He made the first trip from Iowa under the gentle guidance of the real estate promoter and was led to believe that the land was the equal of the Iowa land and was a bargain. It was disclosed that the land produced good crops of rice, cotton, sugar cane and even corn. In order not to act hastily and unwisely he went home and considered the proposition carefully with his wife. He then returned to the small town in Louisiana and proceeded to the farm in order to check his information with Jackson, the colored tenant on the farm. Jackson gave a very satisfactory report as to the

number of bales of cotton, the number of bushels of corn and other products, whereupon he continued his checking by asking Jackson if he did not have considerable money in his pockets as a result of these good crops. Jackson replied that he had no money at all and upon further questioning explained that "de ducks" had gotten everything. The Iowa farmer had heard of the chinch bug, the boll-weevil and the blackbird, but he had never heard of the duck pestilence. Finally Jackson explained that the crops were properly harvested and delivered to the store, but when he went to make settlement it was "de duck" so many dollars for flour, so much for ham, and "de duck" so much for this and that, and when the storekeeper was through there was only $7.87 left for Jackson. The average citizen of the land is very likely to wonder what is left for him out of the investment and profits from such institutions as the national Bureau of Standards.

It is a little difficult to show any particular citizen just where his share of the benefit comes, just as it is difficult to show him what good he gets from the army and navy, and even the post office, in case he does not happen to receive mail or the daily newspaper. In order to show what benefits have accrued to the average man we may well take a picture of the man a half century ago and compare this picture with the average man of to-day, not in his bank account alone but as to the privileges, comforts and safety that he enjoys. Happiness may be so difficult to evaluate that perhaps this were best omitted from the picture. The man who remembers fifty years ago or even less may picture the idle moments on the dry goods box, on the prairie schooner or at the fireside during the long winter evenings with pleasure or with agony. He may have appreciated an apparent lengthening of his life arising from the uneventfulness. To-day the average man has a telephone in his home. He may call up his neighbors or communicate with his relatives across the continent almost at a moment's notice. Formerly he could talk as far as his voice could carry and communicate as far as he could see his neighbor's light. To-day the average man can sit in his own home and hear talks from the most able men in the land. He can hear the finest music that only kings could hear formerly. Almost every man in the land travels in an automobile or in a train or even in an airplane if necessity or his heart's desire calls for it. This makes it possible for a man to cover as much territory in a year now as his ancestors covered in a lifetime. The big earth has apparently shrunk or, looking at it in another way, man has grown in his power so that the earth seems small relatively. The average man gets a very excellent picture of great actors on the movie screen and he enjoys these more frequently and more intently than kings and princes enjoyed the depicting of human life on the stage a century ago. A half century ago the great musicians were heard only

by a relatively small number of people. To-day they are heard not only over the radio, but their accomplishments are recorded in wax and reproduced quite faithfully for all time to come. In a sense greatness has become immortalized. In those days, when only a few could hear and see the prima donnas, only about the same number could wear silk gowns and silk stockings. To-day the number without silk stockings are as rare as those with them a half century ago.

In this half century period we have seen the great developments and additions to man's comforts and power through electricity. We have the street car, the automobile, the elevator and many other inventions carrying man or his possessions by electricity. We have electricity stored up in countless batteries ready to do man's work, starting his automobiles, controlling his railway safety switch signals, furnishing power for his radio and so on. Countless electrical motors render service to every man, either in street cars, elevators, factory machinery, washing machinery, vacuum cleaners or what not. But perhaps the greatest of all is the electric light, which nearly every citizen of the land can enjoy. Likewise every one can cook his meals with gas. Millions to-day have their noon-day meals in cafeterias, lunch rooms and palaces as compared with the cold lunch in a dinner pail less than a quarter of a century back.

A half century ago art was limited to a very few. Aside from the natural beauty of the hills and trees there was not much beauty for the average man. The benefits from improved and more efficient architecture such as we now have in our homes and public buildings, as well as the more pleasing effect in improved landscape gardening, are immeasurable. No value can be placed on increased happiness arising from a more universal appearance of well-dressed folks, beautiful buildings and interior decorations of homes and handsome public conveyances.

In the matter of public health and sanitation the figures show a very great diminution in the death-rate. We can hardly guess as to the amount or the value of the easement of our nerves arising from such blessings as the intelligently controlled water supply, improved machinery, improved surgical apparatus, discoveries in X-rays and radium and the broader knowledge of the properties of matter generally, which have all contributed to practically eliminate plagues, pestilences and the like, and have almost gone so far as to cure incurables.

The man of yore quite frequently had to sleep with his gun over the doorway or under his pillow. To-day a man feels safe to live and travel anywhere without a weapon for defense. Institutions of many varieties make hunger and suffering in old age quite unusual. Over a hundred billion dollars in life and fire insurance

goes far to relieve human nerves from worry and to raise the level of human output.

Every sense that man possesses has been expanded as a result of scientific effort in our civilization. Our increased knowledge about the properties of matter and energy and the commodities of commerce has enormously increased the power of the average man.

With this rough picture of what scientific achievement has added to human comfort, safety and ease of living, there is not left much room for doubt as to who gets the benefit from improvements and savings in the manufacture and distribution of the articles of commerce. When we enter the millionaire's estate and see his well-groomed and well-fed servants, we are led to believe that every one on the payroll is in improved circumstances because of the millionaire's success. Perhaps we wonder after all if he does give an equitable distribution of his wealth in proportion to the worthy efforts of those who help him.

Consider automobile brake linings as an example. The manufacturers are placing a product on the market from three to seven times as good as that three years ago for practically the same cost. I believe that in the severe competition that exists in the automotive industry this saving is handed down to every buyer of an automobile. This means that only one third as many men need be engaged in making automobile brake linings. In other words, these additional men are released to help society in other ways, to develop or raise new agricultural products, to manufacture cosmetics, to discover new wonders of the world or what not. Quite aside from economic considerations there is the advantage of greater human safety. A very large portion of the accidents and deaths from automobiles in recent years have arisen because brake linings were worn so that the driver did not have proper control of the machine. Every improvement in brakes saves the lives of many people.

With regard to the automobile tire, it is common knowledge that the tires are more than twice as good as they were a few years back, and the price is less. I would not go so far as to ascribe a keen desire on the part of any manufacturer to reduce prices voluntarily. It is rather the fundamental and classical law of economics that has prevailed. Competition has led the tire manufacturers to make a better product and to use all the scientific information available from the Bureau of Standards or where not. Improvement in quality and reduction of waste has been stock in hand. The prices have been fixed and lowered in order to get business and maintain profits. The fact is, the rewards of science as applied to automobile tires have certainly been handed down to every automobile owner and to every man who is rendered service by the automobile.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

COTTON FINDS A NEW CAMOUFLAGE

COTTON is a social climber. Handicapped by its lack of the sheen of silk or the luster of linen or the warmth of wool, it is now gaining upon its rivals by aid of the chemist.

Silk, the aristocrat of textiles, gets the gloss that is the envy of the rival fibers from being forced out in a viscous form from the tiny orifices of the spinnerets of the silkworm, solidifying as a single slick smooth cylinder a thousand yards long.

Cotton, on the contrary, if you compare it under a microscope, looks like a short twisted tape, and wool like a rough and scaly rope. Cotton, to quote an old joke, shrinks from soaping—like a small boy. Dipping cotton into strong alkali causes the fibers to shorten and thicken and soften. Seventy-five years ago it occurred to an English chemist, John Mercer, to try what would happen if the cotton were not allowed to shrink. So he kept the thread or cloth on stretchers while it was dipped into a solution of caustic soda and left to dry under tension. The lye took the kinks out of the cotton and softened its surface and this gave it something of the luster of silk. So Mercer immortalized himself, like J. L. MacAdam, the road-maker, by converting his name from a proper noun to a verb, and we have had "mercerized" cotton ever since.

Now a new method of treating cotton has been invented. This is the opposite of the mercerization process for it is produced by acid instead of alkali. Charles Schwartz, of the Philana Company, at Basle, Switzerland, has found that cotton may be made to resemble its other rival, wool, by immersing it in concentrated nitric acid. The fibers become more curly and their surface rougher, and the fabric assumes the texture of a new material to sight and touch. The tensile strength is said to be increased by fifty per cent. and the resistance of the surface against scraping to be improved by two hundred per cent. In wear and warmth and appearance the philanized cloth resembles woolen.

We might suppose that the action of nitric acid on cotton would produce nitro-cellulose, otherwise known as gun-cotton. It would not be pleasant to go about clothed in a high explosive. But in making nitrocellulose sulfuric acid is needed to facilitate the reaction of the nitric. In the present process the nitric acid merely attacks the surface and is all washed out afterwards, or eliminated by alkali. The cotton acquires a yellowish tinge but this may be removed by bleaching. The philanized fabric may be later mercerized and this makes it look like linen. It is said to dye more readily and brilliantly than untreated cotton. One of the leading German dye works is using the new process.

In England nitric acid is being applied to the improvement of ramie, an Indian fiber. When ramie under tension is treated with nitric acid, it acquires a silken luster. When not stretched, it resembles wool. Three minutes' dipping in the cold concentrated nitric acid is sufficient for the

LORD LISTER

Unveiling of the statue of Lord Lister in Kelvingrove Park, Glasgow, on September 17. Lister became professor of surgery in the University of Glasgow in 1860. He began to develop his antiseptic treatment of wounds in 1865.

effect. The fiber gains slightly in weight and considerably in strength and takes dyes better.

The chemist has made a new market for cotton waste by dissolving it completely in nitric acid, alkaline sulfide or acetic acid, and spinning out the viscous fluid into threads of any length, size and shape that he pleases, producing thereby a synthetic fiber that closely simulates silk in appearance if not in strength. Fifty per cent. of what seems to be silk now-a-days comes from the chemical laboratory instead of from the cocoon. By taking on the chemist as an ally, King Cotton is enlarging his realm.

IS IT MOONSHINE?

A COUPLE of years ago an Englishwoman, Miss Elizabeth S. Semmens, was told by an old gardener that seeds planted in the first quarter of the moon germinated better than when planted in the dark of the moon.

Being a scientist as well as a woman, Miss Semmens was endowed with a double dose of curiosity, so she set herself to find out, first, if it were so, and second, if so, why?

Miss Semmens began by exposing different samples of the same seed to moonlight and to sunlight, and she found that more seeds germinated in the moonlit set than in the sunlit set. This indicated that there might be something in the old idea. Anyhow it seemed worth investigating more closely.

At first thought the notion seemed absurd, for moonlight is half a million times weaker than sunlight so how could it be more effective in stimulating plant growth? Besides, moonlight is sunlight, for the moon shines only by the reflected rays of the sun. Has the sunlight undergone any change in quality by being reflected from the moon besides being diminished in quantity? In one respect it has, though nobody ever thought it made any difference. Reflected light is polarized. Light consists of vibrations across the line of sight. If we look at a lamp on the other side of the room, the light waves in the ray coming to us move up and down, right and left, and all the angles in between. But if the ray of light is reflected in a mirror at a certain angle, part of the vibrations, say the sidewise movements, are quenched and the ray of reflected light consists mostly of vibrations in one plane, say up and down. Such light is called polarized because the vibrations have polarity, that is, motion to and fro in one line of direction. The eye can not tell the difference between polarized and ordinary light, and we do not like to think that plants are brighter than we are in any respect.

But we have to admit that there are some things that a plant can do and we can not. One of them is the building up of starch out of glucose which the plant accomplishes with ease, but which we are not yet wise enough to do. The reverse process, the breaking down of starch, we can do and do do in our glucose factories, where thousands of tons of cornstarch are turned into syrup. This is accomplished in the factory by soaking the starch in warm water and adding a little acid. The plant gets the same result by using, instead of acid, a minute amount of a ferment called diastase.

In order to see if polarized light had any effect upon the digestive processes of the plant, Miss Semmens placed some grains of starch in a weak solution of diastase on a microscope slide and threw upon it a beam of polarized light, using a mirror instead of the moon for reflecting the ray because it is handier to handle. Another slide of the same sort was ex-

posed to ordinary diffused sunlight, mostly not polarized, and a third was kept in the dark. The starch was actively attacked and dissolved under polarized light; very slowly in the ordinary sunlight, and not at all in the dark. The temperature was kept the same for all three slides, too low a temperature for the starch to dissolve under ordinary conditions. In some cases artificial light was substituted for daylight, and the light was either polarized by reflection from a glass-covered ferrotype plate or by passing it through a Nicol prism, which consists of a calcite crystal cut in such a way as to divide a ray of ordinary light into two rays, polarized at right angles to each other.

Miss Semmens showed me some of her photographs and slides on a train in Canada last month. Where the polarized light had been at work for awhile the purple starch grains disappear and appear in later slides as coppery spots of glucose very plain and very pretty. A starch grain seen through a microscope looks like a big clam shell. Those that were being eaten away by the diastase under polarized light were notched and nicked all around the edge, like a cake that had been nibbled at by a small boy.

When Miss Semmens announced her results, they were received with much surprise and considerable skepticism. Nobody had ever seen such an effect by polarized light. Which is not strange, considering that nobody ever seems to have looked for it. Also, it was pointed out, the experiments were delicate, the results microscopic and the liability of error great. And finally, what reason was there for thinking that the reactions observed under the microscope actually occurred in the plant.

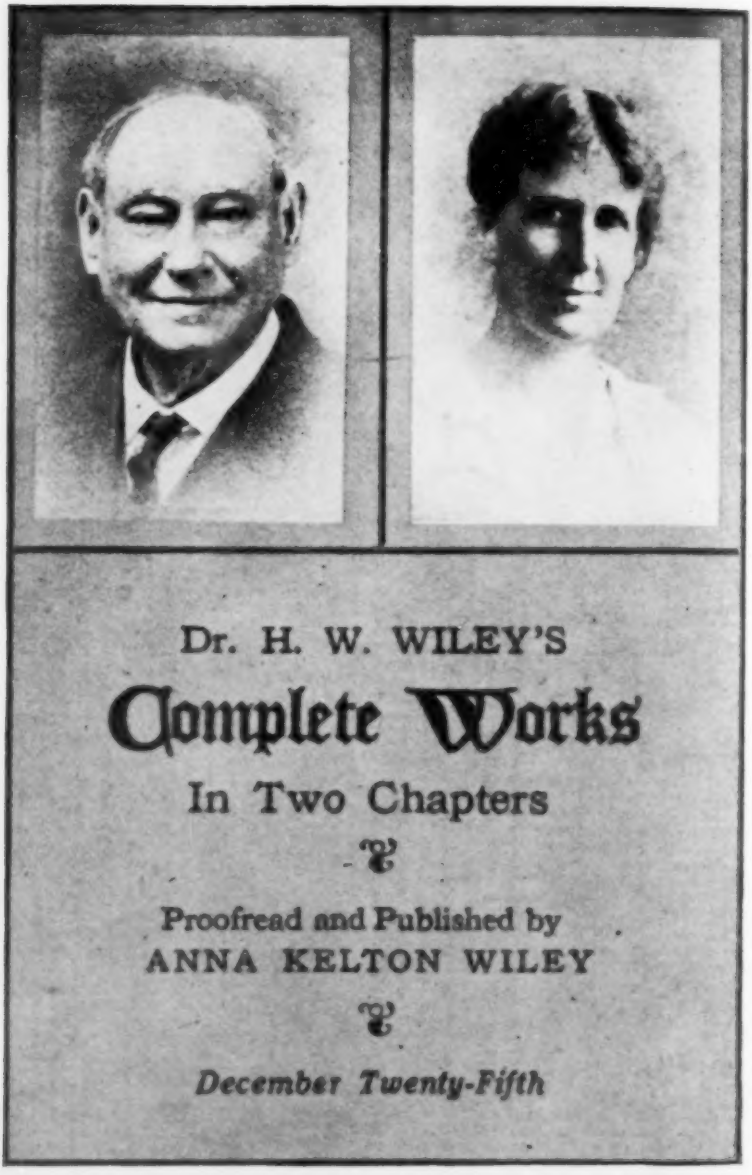
But Miss Semmens—well, you know how women are, the more you tell them that they are wrong the more apt they are to prove themselves right. In spite of the incredulity of experts, she went on with her work. She obtained funds for research from her college, Bedford College for Women in London. She made a convert to her views in Professor Baly, of Liverpool University, who has been carrying on remarkable researches in the synthesis of sugars by electric light, and she went to Liverpool to work with him. Then she crossed the Atlantic to continue her experiments under Professor Lloyd, of McGill University, Montreal.

She has now proved that polarized light thrown upon a living leaf will stimulate the dissolution of starch grains just as it does on a glass slide. Now when the insoluble starch molecule breaks up it splits into two molecules of glucose. Increasing the number of molecules in the cell sap must cause an increase in the solution pressure and so a swelling of the cells. The mouths through which the plant breathes, the stomata of the leaf, are closed and opened by two guard cells which act like lips. When these swell and stiffen the mouth closes. These guard cells are filled with starch and when this breaks down into sugar the cells become turgid and so open the slit. Miss Semmens has found that polarized light has this effect and so may account for the opening and closing of the stomata as the daylight changes.

Just before sunrise, and after sunset, the light we get is largely polarized since it comes to us by reflection from particles in the air. As the sun rises to the noon height, the proportion of direct light becomes greater and of polarized light less. This is the time when starch is formed in the green leaves by the sunshine, but after six o'clock, when the vertical light from the evening sky striking the leaves is polarized, the starch begins to dissolve into glucose.

DR. HARVEY W. WILEY

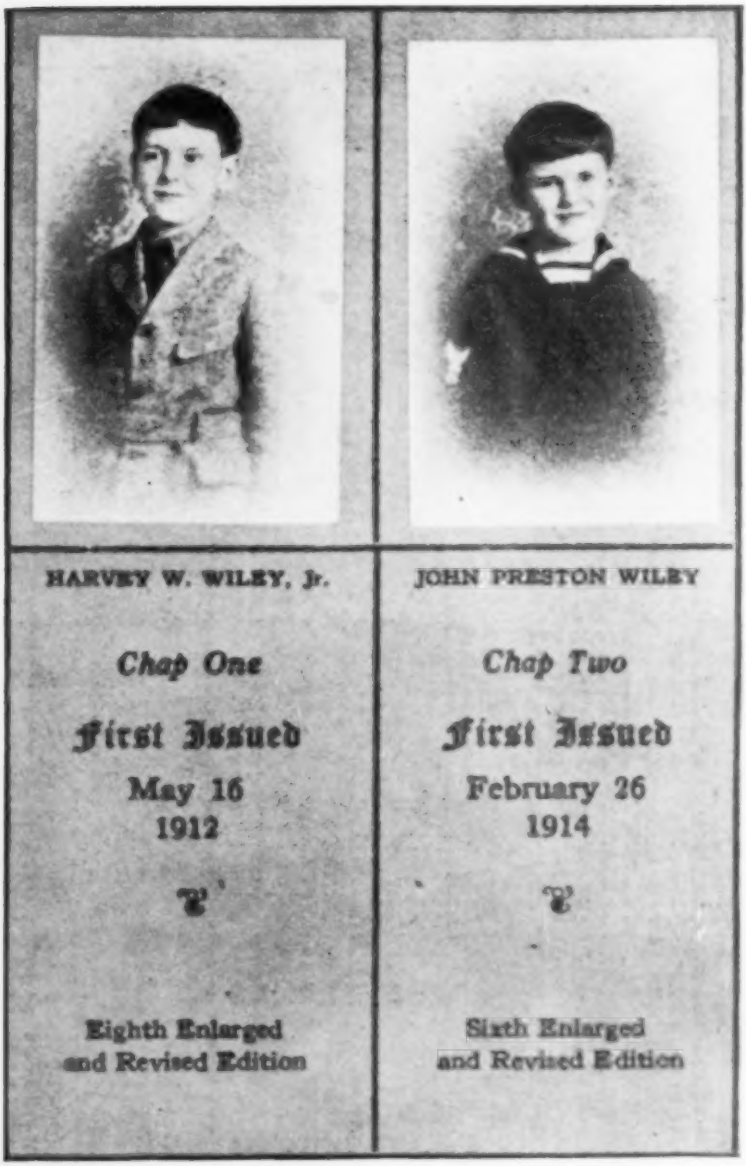
The distinguished agricultural and food chemist, from 1883 to 1912 chief chemist of U. S. Department of Agriculture and for many years professor in George Washington University, whose eightieth birthday was celebrated on October 18.



DR. H. W. WILEY'S

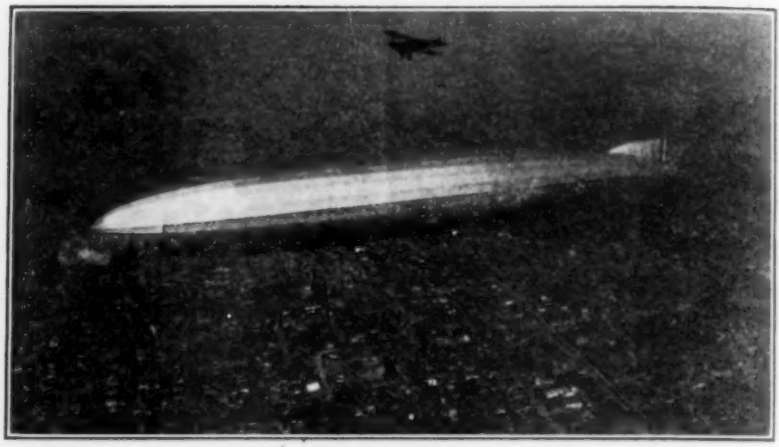
It is a new field into which Miss Semmens has entered and if her results stand the test of further investigations they may give a clew to many a problem of plant and animal life. She herself regards the question as still in the tentative stage and, while she is confident of the validity of her experiments, she religiously resists the temptation to speculate as to their possibilities, at least in public.

It would be foolish of me to rush in where she fears to tread, but I can



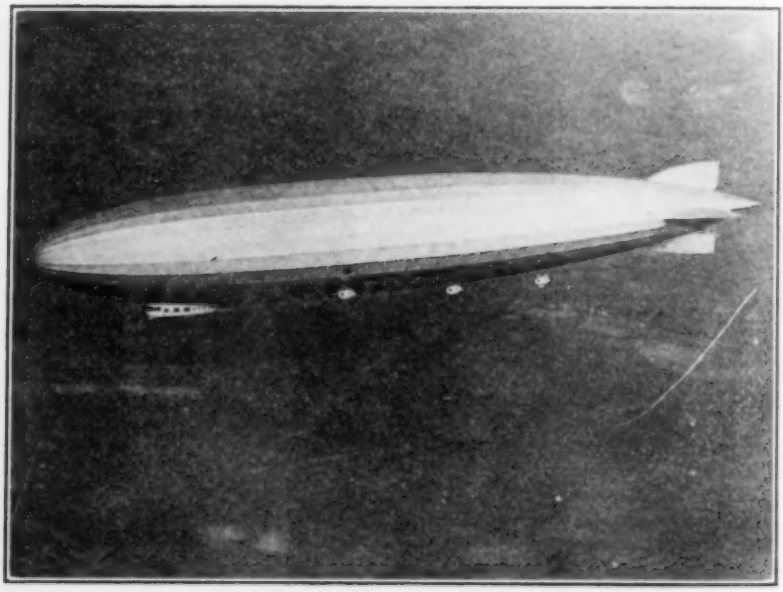
COMPLETE WORKS

not refrain from calling attention to the importance of polarization in vital processes. It is well known that many of the substances found in plants and animals, notably starch and sugar of all sorts, have the peculiar power of twisting around a ray of polarized light as it passes through them. They are, as the chemist calls it, "optically active." The molecule is so constructed as to have a sort of corkscrew action on such light. This peculiarity is taken advantage of in sugar analysis. When the chemist wants to find out how much sugar a beet contains he simply squeezes out



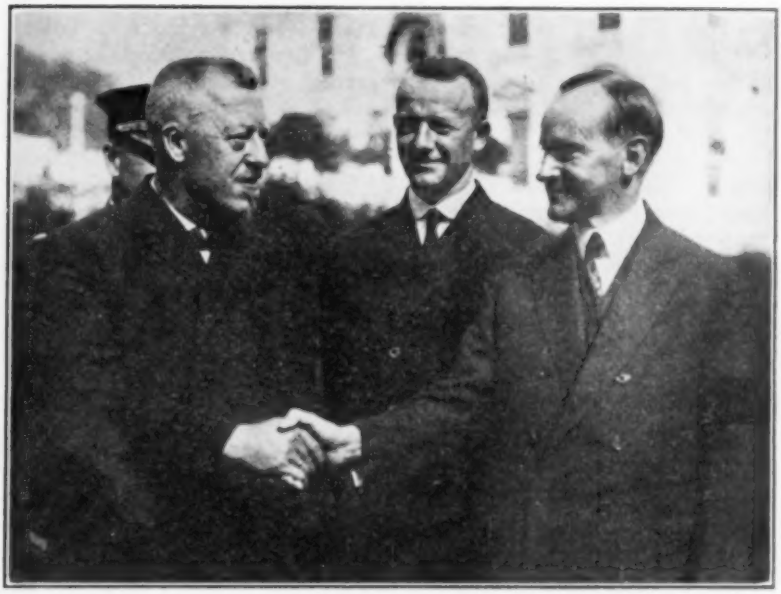
THE SHENANDOAH

Photographed from a navy airplane while passing over Los Angeles.



THE GIANT ZEPPELIN, ZR-3

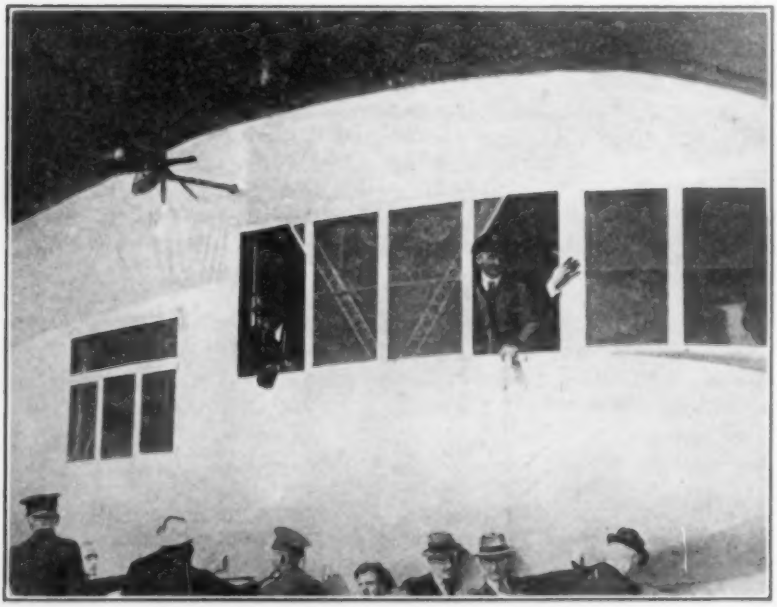
Photographed as she was arriving at the Naval Air Station at Lakehurst, New Jersey, after her eighty-one hour voyage across the Atlantic.



PRESIDENT COOLIDGE GREETING OFFICERS OF THE DIRIGIBLE ZR-3

On the left is Dr. Hugo Eckener, German commander who had charge during the flight to the United States; next to him is Capt. E. A. Lehmann, assistant to Dr. Eckener.

Henry Miller News Picture Service, Inc.



CABIN OF THE GIANT ZEPPELIN, ZR-3

Photographed as she was arriving at the Naval Air Station at Lakehurst.

the juice and puts it into a tube of known length, capped with glass at both ends, looks at a ray of polarized light passing through it, and reads off the percentage of sugar. Some sugars rotate the ray to the right, others to the left, in different degrees but always the same for each sugar. The right and left screw-forms of the same substance often have different physiological effects. Certain kinds of bacteria will eat a left-handed compound while rejecting its right-handed twin. But when a chemist makes one of these vegetable compounds artificially, it usually turns out to be inactive because the two opposing forms are mixed or combined so as to neutralize each other. Since so many natural substances have an effect on polarized light, it would not be surprising after all if it should be found that polarized light had an effect on them.

Then there is reopened the question of the moon which in all ages has been supposed to exert a mysterious influence upon—but I really must stop lest I wander beyond the legitimate range of the scientific imagination.

FEELING THE PULSE OF A STAR

By a new method of analyzing the spectrum of a star, it is now possible to trace regular pulsations through its atmosphere. What caused the fluctuations in the intensity and quality of the light from variable stars has long been a puzzle to astronomers.

By comparing the swinging of a candelabrum with his own pulse beats, Galileo discovered that the period of a pendulum is constant, that is, it does not depend upon the distance through which it swings. Quite similarly the gases in the atmosphere of a variable star are swinging back and forth, in and out, all in the same length of time, but not all through the same distance, as the outermost layer in some of the stars moves very little. Moreover, one layer of the atmosphere receives the motion and passes it on to the next from interior to exterior and back again like a perpetual motion machine. The pulsation of the outer layer takes place last, just as the tipping of the last domino of a falling row; but to make the analogy complete someone would have to stand the dominoes on end again and start the motion backward.

The pulse of the giant star, Eta Aquilae, beats once a week and during this period the star changes from the third to the fourth magnitude, which is easily observed with the naked eye. The change of light accompanies the pulsation through the atmosphere, which carries the energy from the storehouse in the interior to the surface boundary for exportation. During the same time the star changes from a bright orange to a golden color with the increase of radiation.

The cause of these changes has been investigated at the Observatory of the University of Michigan by Professor W. Carl Rufus. By employing a new method of analyzing the rays from this star he has found that the changes of its light are due to alternate compression and expansion of the atmospheric gases.

Compression is a heating process, and the increase of temperature of the radiating surface makes the star shine more brightly. Expansion produces the opposite effect. So with every beat of the pulse of the star these alternating physical processes are revealed in the rate of flow of its energy as seen by the eye and interpreted by the mind of man.

The source of this inexhaustible supply of energy, however, is a problem that has completely baffled the astronomers in spite of their giant telescopes, their ingenious spectroscopes and sensitive photometers. Energy seems to be a final product in the quest for scientific truth or the most primitive star-stuff from which the universe evolved.

INDEX

NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS

Agricultural Production, C. G. WILLIAMS, 263
Air, Free, 218
Alchemist, PAUL D. FOOTE, 239
Archeological Conference, 220
Astronomical Observatories in the United States, W. C. RUFUS, 120
Astronomy of Shakespeare, JOHN CANDEE DEAN, 400

BAKER, RAY PALMER, Rensselaer Polytechnic Institute, 337
Bayliss, Sir William, 442
BERRY, EDWARD W., Mississippi Gulf in the Eocene, 30
BIRKHOFF, GEORGE D., Relativity, 18, 180
Botanists, Memorable, WILLIAM TRELEASE, 53
Botanizing in Ecuador, A. S. HITCHCOCK, 611
BRAGG, WILLIAM HENRY, Carbon Atom, 578
BROWN, F. C., Research, 655
Bruce, Maj.-Gen. Sir David, 328
BURGESS, GEORGE K., Scientific work of the Government, 113

Cactus in Australia, 217
CAETANI, GELASIO, Leonardo da Vinci, 449
Carbon, Atom, WILLIAM HENRY BRAGG, 578
CARMICHAEL, R. D., An International Mind, 47
CHAPIN, F. STUART, Social and Economic Sciences, 390
Chemistry and the Alphabet, 107
Civilization, The Senility of, 559
COCKERELL, T. D. A., A Journey in Siberia, 415
Cooperation in Low Life, 103
Cotton, 661
Cubical Cultivation, 330

Date-Palm, PAUL POPENOE, 313
DAVIE, MAURICE R., Immigration and the Declining Birthrate, 68
DAVIES, GEORGE R., Population and Progress, 598
DAVIS, DAVID J., Diseases, 368
DEAN, JOHN CANDEE, Astronomy of Shakespeare, 400
Desert Tragedy, DAVID STARR JORDAN, 327
Disease, The Physical Basis of, THE RESEARCH WORKER, 156, 281, 407, 520, 648
Diseases, DAVID J. DAVIS, 368
Dreams to Order, 335

Education escaping from the Schoolroom, 223
Electrical Engineering, A Hundred Years of, G. W. O. HOWE, 290
Elements, Disintegration of the, ERNEST RUTHERFORD, 561
Evolution, WILLIAM PATTEN, 635

FAIRCHILD, H. L., Development of Geologic Science, 77
Fecundity, HORNELL HART, 527
FOOTE, PAUL D., The Alchemist, 239
Forest Properties, Management of, S. B. SHOW, 548
Franklin Institute, 552, 554

Gases Heavier than Lead, 441
Geologic Science, Development of, H. L. FAIRCHILD, 77
Green-headed Idea, 443
GREGORY, HERBERT E., The Pacific Science Congress, 271

HAAS, WILLIAM H., S. A. Indian, 188
HART, HORNELL, Fecundity, 527
HAYFORD, JOHN F., Waters of the Great Lakes, 588
Health, Contagious, 221
HEGNER, ROBERT W., Parasitism, 140
Heredity and Environment, H. S. JENNINGS, 225
HEYL, PAUL R., The Master Key, 5
HITCHCOCK, A. S., Botanizing in Ecuador, 611
HODGE, F. W., Skidding on the Road to Science, 43
Hofmeister, Wilhelm, WILLIAM A. LOCY, 380
Hot Weather Clothing, 333
HOWE, G. W. O., A Hundred Years of Electrical Engineering, 290
HOWERTH, IRA WOODS, Law of Inequality, 502

Immigrants, Standards for, R. DEC. WARD, 533
Immigration and the Declining Birthrate, MAURICE R. DAVIE, 68
Indian, of S. A., WILLIAM H. HAAS, 188

Indians, "Pale Face," 222
Inequality, Law of, IRA WOODS HOWERTH, 502
International, Critical Tables, 446, 448; Mind, The Need of, R. D. CARMICHAEL, 47

JENNINGS, H. S., Heredity and Environment, 225
JORDAN, DAVID STARR, A Desert Tragedy, 327
Life, The Origin of, CHARLES B. LIP-
Life The Origin of, CHARLES B. LIPMAN, 357
Light, Speed of, 553
LIPMAN, CHARLES B., Origin of Life, 357
LITTLE, ARTHUR D., Research, 165
LOCY, WILLIAM A., Wilhelm Hofmeister, 380
LORENTZ, HENDRIK ANTOON, The Radiation of Light, 170

McDOUGALL, WILLIAM, Purposive Striving, 305
McMillan, Donald B., 444
Master Key, PAUL R. HEYL, 5
Mathematics, Pure, G. A. MILLER, 496
Medicine, Philosophy in, HORST OERTEL, 512
Melting Pot, The, 555
Mendenhall, Thomas Corwin, 332
Mental Hygiene, STEWART PATON, 625
MILLER, G. A., Pure Mathematics, 496
MILLER, ROBERT CUNNINGHAM, The Shipworm, 434
Mississippi Gulf in the Eocene, EDWARD W. BERRY, 30
Moonshine, 663

National Academy of Sciences, 102, 106, 108, Dedication, 110

OERTEL, HORST, Philosophy in Medicine, 512

Pacific Science Congress, HERBERT E. GREGORY, 271
Parasitism, ROBERT W. HEGNER, 140; among the Insects, FRANCIS METCALF ROOT, 479
Pasteur, Bust of, 558
PATON, STEWART, Mental Hygiene, 625
PATTEN, WILLIAM, Evolution, 635
Physical Basis of Disease, THE RESEARCH WORKER, 156, 281, 407, 520, 648
POPENOE, PAUL, The Date-Palm, 313
Population and Progress, GEORGE R. DAVIES, 598
Progress of Science, 103, 217, 329, 441, 553, 661
Pulse of a Star, 670
Purposive Striving, WILLIAM McDOUGALL, 305

Radiation of Light, HENDRIK ANTOON LORENTZ, 170
Relativity, GEORGE D. BIRKHOFF, 18, 180
Rensselaer Polytechnic Institute, RAY PALMER BAKER, 337
RESEARCH WORKER, The physical Basis of Disease, 156, 281, 407, 520, 648
Research, the Mother of Industry, ARTHUR D. LITTLE, 165; the Profits of, F. C. BROWN, 655
ROOT, FRANCIS METCALF, Parasitism among the Insects, 479
RUFUS, W. C., Astronomical Observatories in the U. S., 120
RUTHERFORD, ERNEST, Disintegration of the Elements, 561

Science, Skidding on the Road to, F. W. HODGE, 43; the Next, ARLAND D. WEEKS, 63
Scientific Work of the Government, GEORGE K. BURGESS, 113
Shipworm, The, ROBERT CUNNINGHAM MILLER, 434
SHOW, S. B., Management of Forest Properties, 548
Siberia, A Journey in, T. D. A. COCKERELL, 415
SLOSSON, E. E., Progress of Science, 103, 217, 329, 441, 553, 661
Social and Economic Sciences, F. STUART CHAPIN, 390
Stability, T. WINGATE TODD, 632
STRÖMBERG, GUSTAF, Motions of the Stars, 465
Sweeter than Sugar, 111

Table Trick and what it teaches, 447
Tamed Inventions, 105
TODD, T. WINGATE, Stability, 632
Toronto, University of, 334
TRELEASE, WILLIAM, Memorable Botanists, 53

da Vinci, Leonardo, GELASIO CAETANI, 449
Vitamins, 329

WARD, R. DEC., Standards for Immigrants, 533
Waters of the Great Lakes, JOHN F. HAYFORD, 588
WEEKS, ARLAND D., The Next Science, 63
Wiley, Harvey W., 665
WILLIAMS, C. G., Agricultural Production, 263
Woodward, Robert Simpson, 216

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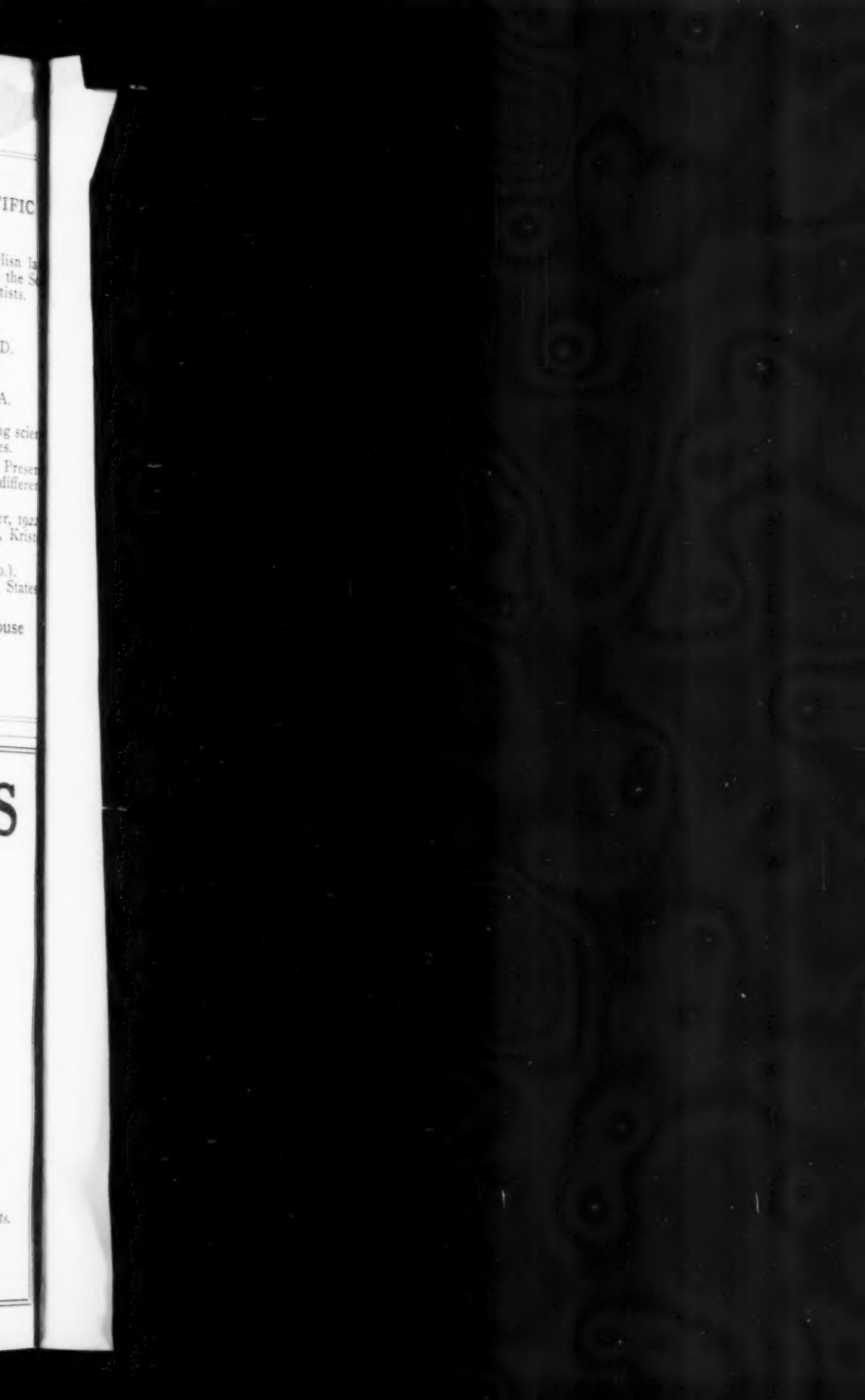
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